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AMERICAN WATER WORKS ASSOCIATION

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OFFICERS OF THE AMERICAN WATER WORKS ASSOCIATION (Continued)

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JOURNAL
OF THE
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The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings
Discussion of all papers is invited

Vol. 20 SEPTEMBER, 1928 No. 3

ANNOUNCEMENT OF INCOMING PRESIDENT

The advancement made by our association in recent years, which has come about through the effective work performed by the Standardization Council, and the officers and members of the association, has made it necessary to consider thoroughly the needs of the association and how these needs can best be met.

The organization of the American Water Works Association and its plan of operation must provide certain features if it is to adequately represent the water works fraternity of the North American Continent. From the viewpoint of your president these are:

1. The Executive committee should be so constituted as to represent effectively all sections of the country, and should devote the necessary time to planning the work of the association at periods other than when the association is in convention.

2. The meetings of the association should be of such number, and in such locations that the entire membership would have a reasonable opportunity to attend a general meeting each year, although two or three years may elapse before a member in certain sections would be able to attend a general meeting without travelling a substantial distance to reach the place of meeting.

3. The journal should reflect in its papers current practice and development in the water works art.

4. Our manual should be revised to set forth more adequately and fully what is recognized as best practice in water works construction, operation and maintenance.

5. The meetings should generously provide time and opportunity for the exchange of experience in both the large and small things that make up the superintendents' activities, and the importance of the superintendents' meetings should be emphasized.

6. The committee work should be organized and encouraged so that the membership may have the benefit of the systematic consideration of important water works problems by those who are specially experienced in solving such problems.

7. The secretarial staff should be adequate to effectively aid the membership in carrying on the association work without unreasonably burdening any of the members.

8. The relationship between the association and the manufacturers should be developed on a sound business basis, and the manufacturers given opportunity to take part in the association meetings.

During the past two years there has been both formal and informal discussion of the association's problems which has crystallized in the executive committee at the San Francisco convention authorizing the then retiring president, Mr. James E. Gibson, to appoint a committee of seven members to formulate and present a suitable plan and draft the necessary changes in the Constitution to provide for the future work of the association. The executive committee appropriated $1500 to meet the expenses of the committee. The committee appointed by Mr. Gibson is as follows:

R. L. Dobbin, Superintendent of Water Works, Peterborough, Ont., Canada, *Chairman.*

Geo. H. Fenkell, Superintendent and General Manager, Board of Water Commissioners, Detroit.

W. W. DeBerard, 160 N. La Salle St., Chicago.

W. S. Cramer, Chief Engineer, Water Company, Lexington, Ky.

Robert Spurr Weston, Consulting Sanitary Engineer, Boston, Mass.

George W. Pracy, Superintendent, Spring Valley Water Co., San Francisco, Calif.

Dennis F. O'Brien, President, A. P. Smith Mfg. Co., East Orange, N. J.

Associate Members, ex-officio, Abel Wolman, Editor, and Beekman C. Little, Secretary of the American Water Works Association.

It is hoped that this committee may be able to make a preliminary report in the fall of this year, and submit what will virtually be a final report to the executive committee at its meeting to be held in January, 1929.

Your president, as a result of discussion of the problems with various members of the association and water works manufacturers,

has certain views as to the action that it seems desirable for the association to take in planning for its future work, and will express these views in the hope that each member will give some thought to the questions involved and will advise Mr. Dobbin, chairman of the special committee, as to the action such member believes should be taken. It is the desire of the executive committee that the views of the members be presented to the special committee so that the committee will have a representative cross-section of these views to aid them in formulating its recomendations. Your president trusts that, irrespective of whether his views do or do not appeal to individual members, such members will freely express their views to the committee. His views are as follows:

a. The executive committee should consist of a president and treasurer, elected by the membership at large, a director for each section, elected by the membership of the section and serving for a period of three years, a director elected by the Manufacturers Association, the chairmen of the Publication, Water Works Practice, and Finance committees, if the Finance committee is to be continued, the two latest living past presidents, the editor, and the secretary.

b. Each year there should be at least three general meetings of the association, one of which will be designated by the executive committee as the annual convention. These meetings should be held in those sections of the North American continent into which said area is divided by the executive committee, the place and time of holding each regional meeting to be determined by the sections in the area which is represented by the meeting, the place and time to be subject to the approval of the executive committee. The program and exhibits at each regional meeting are to be substantially of equal importance as planned for the annual convention meeting. The superintendents' portion of the program should generously and adequately provide for exchange of views and discussion on maintenance and operation problems.

c. The revision of the manual will require the collection of data and the presentation of these data in proper form and thus present modern water works practice more adequately than it is presented in the present manual. Our present manual is a most excellent first edition, but needs substantial revision.

d. The committee on Water Works Practice is expected to select the various phases of water works construction, maintenance and

operation, including materials and equipment, which should form the subject of a special study by committees. The necessary personnel for the different committees would have to be selected and then the work performed by such committees followed up to see that the committees were satisfactorily functioning. The Publication committee would have the important duty of preparing three regional meeting programs a year, in place of the one annual convention program. To perform such work without making an unreasonable demand on the volunteer time of members necessitates a thoroughly competent executive secretary to aid the chairmen of these two important committees and of other committees in carrying out the committee work.

e. For virtually the life of the association the manufacturers have furnished the greater part of the entertainment, and have handled the exhibit space at conventions, making no payment to the association for the privilege of exhibiting, other than furnishing the aforesaid entertainment. This relationship should be placed upon a definite business basis, under which the manufacturers would probably continue to handle the assignment of exhibit space, but would pay the association a suitable fee for all exhibit space occupied, and would not be called upon to pay for any entertainment. The entertainment might be provided under a program agreed to between the representatives of the manufacturers and the association, and the manufacturers aid the association by engaging the necessary talent and attending to other similar details if requested to do so by the association. The association would, however, pay all the bills, using for this purpose a portion of the money obtained from the exhibit space fee, and also the money that would be obtained by charging every one in attendance on the convention, members, guests, manufacturers and their representatives, a registration fee, which would be less than the cost of the entertainment provided, but which would be a substantial aid towards meeting the expense of such entertainment.

f. The committee on Water Works Practice is a new committee which was set up by the Executive Committee at the San Francisco convention to take the place of the Standardization Council. The Standardization Council was a self perpetuating body that was not officially responsible to the Executive Committee. It seemed to the Executive Committee that all of the work of the association should be under the control of the Executive Committee, and that it was there-

fore advisable to discontinue the Standardization Council and substitute therefor the new committee on Water Works Practice. This action was agreed to in principle by several of those who were active members of the Standardization Council and those who had been active in the work of said Council. The Standardization Council was mainly responsible for the preparation of the Manual, and for the excellent committee work that was performed by many committees in connection with the preparation of the Manual. The association is greatly indebted to its members who served on the Standardization Council, and the changing of said Council into the committee on Water Works Practice is believed to be a forward step in increasing the usefulness of the association work.

While it is impossible in the space reasonably available to set forth many details that are of importance and must be worked out, the foregoing gives an outline that can be used for purposes of discussion. The membership generally are again urged individually to take an active part in the consideration and solution of their association problems.

Wm. W. Brush,
President.

THE SAN FRANCISCO WATER SUPPLY[1]

By G. A. Elliott[2]

San Francisco, unlike many of the early settlements in California, was not located geographically primarily because of the existence in the vicinity of a visible water supply, but owes its position to its magnificent harbor. San Diego, Los Angeles, Monterey and other early Spanish settlements, were all located in close proximity to rivers. Aside from a few small creeks and springs, now obliterated by the development of the city, there are only two minor water sources within the city limits, one, Lobos Creek in the Presidio, now used to furnish water to the extent of 2 million gallons daily to the army units stationed there, and the second, Lake Merced, with a daily capacity of about 3½ million gallons. The average annual rainfall in the city is 22.4 inches, practically all of it occurring between the months of November and April, and the area for some distance around San Francisco Bay is designated climatologically as semi-arid.

Situated at the extreme tip of a peninsula upon which a comparatively small quantity of water has been developed, and cut off by the bay from the nearest sources of magnitude, it has been necessary to go some distance to develop the present supply of 66 million gallons daily. More than two-thirds of the present development requires transportation of the water over 48 miles and the supply necessarily crosses the bay in submarine pipes. Future development of water supply by the municipality, which recently voted bonds to purchase the plant of the Spring Valley Water Company, will add 120 miles of transmission conduit, making the total distance from Hetch Hetchy reservoir in the Sierra Nevada range to the city about 168 miles. Due to climatic conditions large storage is necessary and fortunately reservoir sites with a present developed capacity of 30 billion gallons, which can be increased, have been constructed by the Water Company within 12 miles of San Francisco, into which the water of the Hetch Hetchy development can be poured.

[1] Presented before the San Francisco Convention, June 12, 1928.

[2] Vice President and Chief Engineer, Spring Valley Water Company, San Francisco, California.

During the time of the Mexican occupation, beginning about 1835, and in fact until sometime after California became a part of the United States, no attempt was made to install a water system. Prior to 1858 water was delivered in carts to all of the consumers who were not fortunate enough to have access to a well or spring. The rapid growth of San Francisco following the discovery of gold, intensified the need for a regular water distributing system and in 1858 the San Francisco City Water Company was organized for the purpose of developing Lobos Creek and delivering its water to consumers. At that time the populated section was the flat area in the vicinity of the Bay and the task of bringing Lobos Creek to the homes was one of considerable difficulty for those days. The water was carried in flume and tunnel around the north shore of the bay to a pumping station at the foot of Van Ness Avenue and there elevated to Francisco and Lombard reservoirs, both of which are still in use.

The year 1860 saw the beginning of Spring Valley Water Works, organized by George Ensign. The name came from a spring in the hollow between Clay and Broadway, Powell and Mason streets, called the Valley Spring. But the Company's first water supply was Islais Creek, tapped at a point west of the present Mission Street viaduct. The water was carried by flume and pipeline to a reservoir at 16th and Brannan streets. The yield was 200,000 gallons a day.

More enterprising than its elder competitor, Spring Valley proceeded far afield to develop water on a large scale, and chose strategic positions for its big distributing reservoirs within the city.

San Francisco's neighboring county to the south is San Mateo, a region of beautiful valleys and mountains thickly wooded. Spring Valley immediately realizing that San Francisco could not be supplied from streams like Lobos and Islais, went prospecting for water down the peninsula. Within two years the Company was building its first catchment reservoir, at Pilarcitos high in the San Mateo hills, and its first big distributing reservoir, Lagunda Honda, in San Francisco. By 1862 Pilarcitos water was flowing by gravity 32 miles to Lagunda Honda. Two years later Pilarcitos was being enlarged. By 1865 Spring Valley had absorbed the San Francisco City Water Company, taking over the Lobos Creek supply and structures, the pumping station at Black Point, the two reservoirs on Russian Hill, and the pipes in the streets. Ever since then Spring Valley alone has borne the responsibility of supplying this city with water. The corporate name was changed to Spring Valley Water Company in 1903.

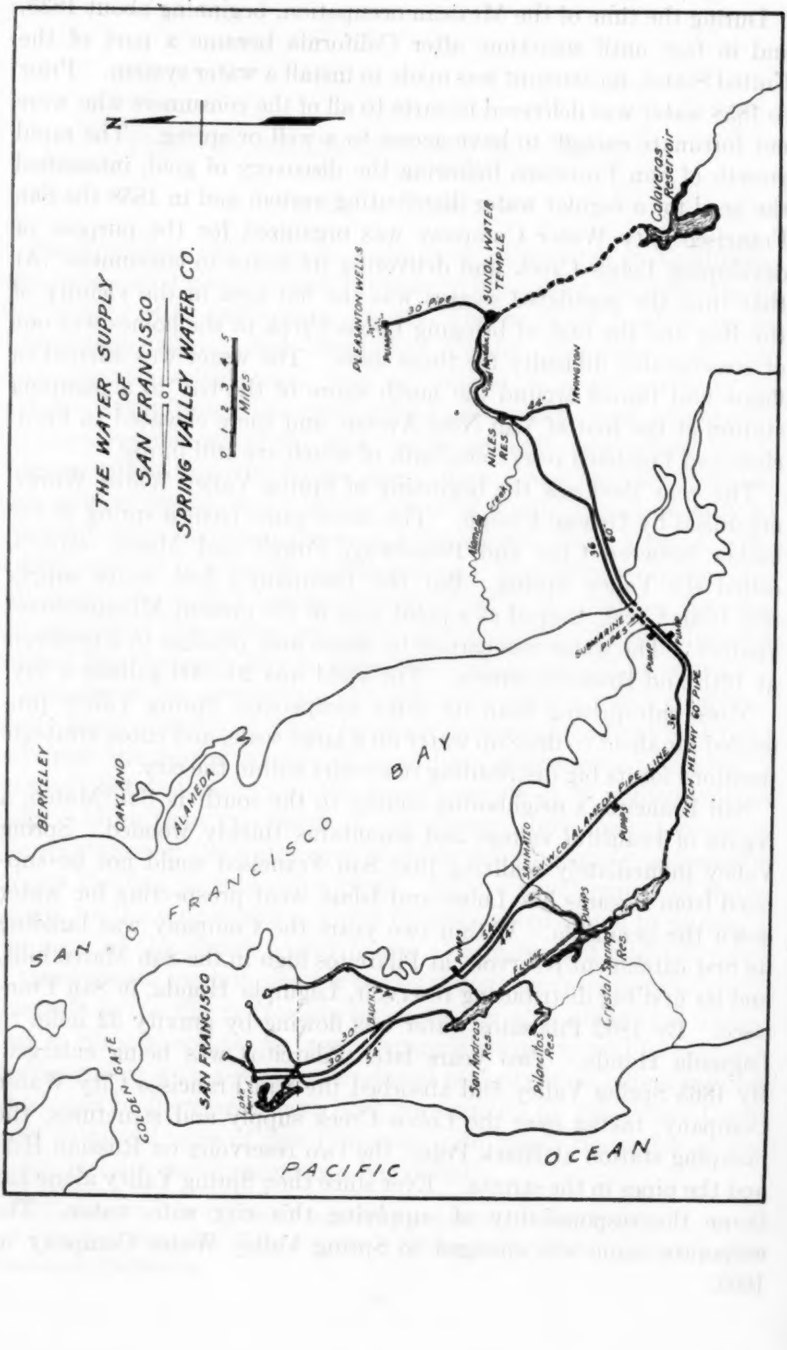
THE WATER SUPPLY
OF
SAN FRANCISCO
SPRING VALLEY WATER CO.
Miles
Calaveras Reservoir
SUNOL WATER TEMPLE
PLEASANTON WELLS
30" PIPE
IRVINGTON
NILES RES.
SUBMARINE PIPES
HETCH HETCHY 60" PIPE
ALAMEDA PIPE LINE
PUMPS
Crystal Springs Res.
Pilarcitos Res.
San Andreas Res.
FLUME
SAN FRANCISCO
GOLDEN GATE
BERKELEY
OAKLAND
ALAMEDA
SAN FRANCISCO BAY
PACIFIC
OCEAN

FIG. 1

Following Pilarcitos reservoir San Andreas was built in 1868 and Crystal Springs dam in 1890. The completion of Calaveras dam in 1924 brings the development to the present.

As of 1928 the developed capacity of the Spring Valley Water Company is 66 million gallons daily, supplying a daily average consumption of 49 million gallons. About 2.8 million gallons daily of this amount are used along the route of the transmission lines outside of San Francisco. The Company owns 79,515 acres of land, consisting of watershed property and land overlying the subterranean sources as well as reservoir sites and that used in connection with the structures necessary for water-supply purposes. In the transmission of water from the sources to the distributing system use is made of $7\frac{1}{4}$ miles of tunnels, 13.8 miles of flumes and concrete aqueducts, and 101 miles of riveted pipe ranging in diameter from 30 inches to 54 inches. There are 713 miles of pipe in the city distributing system, supplying over 100,000 service connections and 4950 fire hydrants.

The present supply is derived from catchment reservoirs in Alameda, San Mateo, and San Francisco counties, and from wells in the Livermore Valley and infiltration galleries in the Sunol Valley, both valleys being situated in Alameda County. The region in the vicinity of San Francisco is designated as semi-arid, and past experience has proved the necessity for a storage capacity equal to three years' demand in order to continue the supply through the dry cycles which occur with regularity. This requirement, together with the fact that, typical of California streams in this vicinity, all of the runoff occurs in the winter season, has made it necessary to build large storage reservoirs. The total storage capacity of the Company is 64,800,000,000 gallons. The Company owns practically the entire drainage area tributary to the reservoirs in San Mateo County, the habitation on the drainage being limited almost entirely to its employees, a circumstance of great importance in preventing contamination of the water.

The Peninsula supply, as those sources situated in San Mateo and San Francisco are known, consists of four reservoirs. Pilarcitos reservoir is situated about midway between the Pacific Ocean and the Bay of San Francisco, about 11 miles south of the city. An earth dam 70 feet high, built across Pilarcitos Creek in the year 1867, impounds the runoff from 5.2 square miles of watershed, creating a lake which holds 1 billion gallons of water. The dam, with slopes of $2\frac{1}{2}$ and 2 to 1, was constructed as a dry fill, with a puddled-clay core, the earth being spread in thin layers and rolled.

The reservoir is at an elevation of approximately 700 feet above sea-level. The surrounding hills are at a much higher elevation, reaching 1875 feet, and their slopes are covered with a heavy tree and brush growth. The average annual rainfall of 49 inches, the largest precipitation at any point of the water system, usually provides a greater annual runoff than can be stored in the lake, and the surplus is allowed to pass on through tunnels and flumes to either San Andreas or Crystal Springs reservoir.

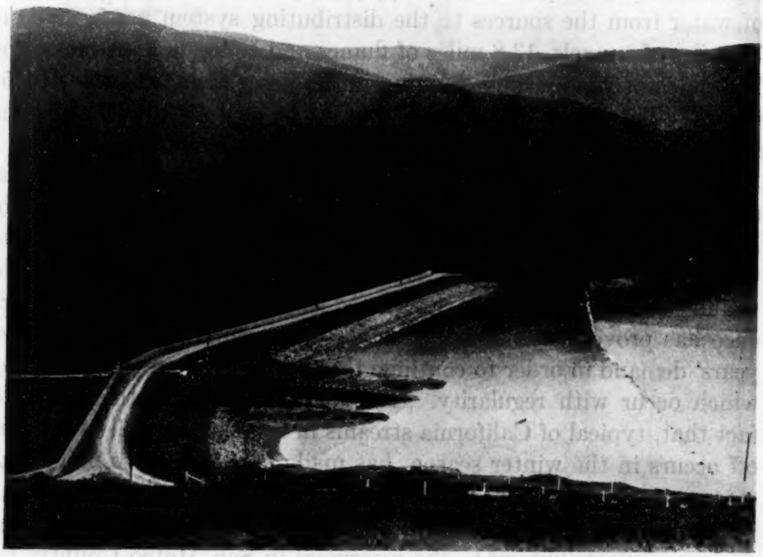

FIG. 2. SAN ANDREAS DAM

San Andreas reservoir is located in the next valley to the east of Pilarcitos and about 2 miles to the north. The dam was constructed in 1868 in the same manner as Pilarcitos, its height being 95 feet. The capacity of the reservoir is 6 billion gallons, and the average annual rainfall is about 40 inches. The drainage area directly tributary to the reservoir is 8.4 square miles. The runoff from about one square mile of the upper area drained by San Mateo Creek, which is naturally tributary to Crystal Springs reservoir, is diverted by means of the Davis Tunnel through the ridge to the west of San Andreas and finds its way into San Andreas reservoir.

Crystal Springs reservoir occupies the lower portion of the same valley that contains San Andreas, and is about 13 miles south of San Francisco. It was formed by the construction of a concrete dam 154 feet high, containing 157,200 cubic yards of concrete built in 1887–90. Crystal Springs reservoir has a total length of about 7 miles, a storage capacity of 22,500,000,000 gallons, and an average annual rainfall of 29 inches. The lake is divided into two parts by an earth dam built 3 miles from its southern end in 1877, creating the original Crystal Springs reservoir. The concrete dam was built of interlocking blocks. The blocks are 40 feet long, 8 feet high, and 30 feet wide. Alternate blocks were built in place, and the spaces between them afterwards filled in with concrete in order to minimize the effect of the shrinkage due to the setting of the concrete. The dam was built with sufficient dimensions so that it can be raised in the future without adding to its thickness. This is a very valuable feature, as large storage in the vicinity of San Francisco is very desirable, due to the distance water must be brought to meet the future needs of the city.

The combined average daily production of Pilarcitos, San Andreas and Crystal Springs reservoirs is 18 million gallons.

Lake Merced, in the southwest corner of San Francisco, is a natural lake whose capacity was increased to 2,500,000,000 gallons by the construction of an earth dike about 15 feet high across its outlet. It is situated about half a mile east of the Pacific Ocean, practically at sea-level. Water reaches it through the medium of an average annual rainfall of 23 inches, which falls on the sandy drainage area through which it percolates, finally entering the lake in the form of springs. All surface drainage which might enter Lake Merced is diverted around the reservoir and carried off so as to decrease the danger of contamination. The normal daily productivity is $3\frac{1}{2}$ million gallons.

The Alameda sources are all contained within the drainage area of Alameda Creek, a stream which drains over 600 square miles of watershed located in the Coast Range mountains on the east side of San Francisco Bay. The topography of the area varies greatly, ranging from the flat valleys of Sunol and Livermore, at elevation 220 feet, through rolling foothills to the rugged slopes of Mt. Diablo, Black Mountain, and Mt. Hamilton, at elevation 4209 feet above sea-level. The rainfall varies from a minimum of 15.26 inches at Livermore to 30.50 inches at Mt. Hamilton. Due to the large drainage area, the

average annual runoff is 47 billion gallons. The principal tributaries of Alameda Creek are the Arroyo Honda, draining 100 square miles; Upper Alameda Creek, draining 40 square miles; San Antonio Creek, draining 39 square miles; Arroyo Valle, draining 150 square miles; Arroyo Mocho, draining 38 square miles. The two last-named streams cross the gravel-filled Livermore Valley and are the principal sources of its underground supply. Uniting with other minor streams that flow into L vermore Valley, the Arroyo Valle and Arroyo Mocho form Laguna Creek, through which the runoff flows to Alameda Creek at Sunol. The Arroyo Honda, Upper Alameda, and

Fig. 3. Calaveras Dam

San Antonio combine to make Calaveras Creek, which crosses the Sunol Valley to join with Laguna Creek, forming Alameda Creek, which flows down Niles Canyon to San Francisco Bay.

Three storage locations are to be found on the principal tributaries of Alameda Creek, one of which has been developed on the Arroyo Honda, and is known as Calaveras reservoir. It is located about 9 miles south of Sunol. An earth-and-rock dam, the lower portion of which was constructed by the hydraulic-fill method, and the upper part with a rolled-clay core supported by loosely placed rock, impounds the runoff from 100 square miles of watershed. The height

of the dam is 220 feet above bedrock, and the capacity of the reservoir is 32,800,000,000 gallons. Based on past records, the daily productivity at present is 38,200,000 gallons. When the Upper Alameda Tunnel, which is now under construction, is completed the runoff of an additional 40 square miles of drainage area will be transported a distance of 9700 feet into Calaveras reservoir.

The San Antonio and Arroyo Valle reservoirs, projected for the future, are situated on the streams of their respective names.

In addition to the surface storage described, the Spring Valley Water Company makes use of two underground sources of supply, known as Sunol and Livermore valleys. The Sunol Valley is a gravel-filled depression with a surface area of 1300 acres, located at the upper entrance to Niles Canyon, through which the entire drainage of the Alameda system of over 600 square miles must pass on its way to the bay. A low dam at the canyon entrance backs up the water in the gravels from which it is abstracted through an infiltration gallery. Water is taken from the Livermore Valley through the medium of wells ranging in depth from 50 to 600 feet. At the present time 75 wells are equipped with pumping units, which are operated when necessary. The Livermore Valley floor has an area of 35 square miles. Rainfall on an area of 412 square miles supplies the streams which pass through the valley.

In transporting the water from the sources of supply to the city distributing reservoirs the principal medium is riveted pipe. The character of the water as well as the soil in which these pipes are laid is such that deterioration has been slow. A part of the first pipe laid to bring Pilarcitos water to San Francisco was removed only a few years ago after a continuous use of over fifty years. Such flumes as are used are constructed of California redwood, which has a long life, and the tunnels, the longest of which is 7500 feet, are lined with brick or concrete.

Pilarcitos water flows through 4921 feet of tunnels, 5280 feet of wood flume, and 730 feet of 44-inch and 4488 feet of 22-inch riveted pipe into San Andreas reservoir. In the event of an overflow through the Pilarcitos wasteway, a dam about two miles downstream diverts this flow into a conduit consisting of $5\frac{3}{10}$ miles of flume, $1\frac{3}{10}$ miles of tunnel, and $\frac{4}{10}$ mile of 44-inch pipe which carries it to San Andreas. The outlet from San Andreas reservoir is a tunnel roughly 4 feet wide, 6 feet high, and 2800 feet long. A 44-inch pipe receives the water from this tunnel at elevation 367 feet and carries it to Baden, a dis-

tance of about 27,000 feet. At Baden this pipe divides into two 30-inch lines, one 43,000 feet long leading to College Hill reservoir, with a capacity of 13,500,000 gallons at elevation 255 feet, and the other 36,000 feet long known as the Merced branch, going to Central Pump at elevation 190 feet, located at Sloat Boulevard and 23rd Avenue in San Francisco. The Merced branch passes through the Rancho de la Merced, an old Spanish grant, and a spur-line 16 inches in diameter enables water to be taken from the pipe and pumped to Lake Honda distributing reservoir at elevation 370 feet by Ocean View pumps situated near the San Francisco county line. Ocean View pumps consist of two units with total daily capacity of 6 million gallons. This station can also take water from the College Hill branch, which passes just to the east of the pumps. A second spur from the Merced branch 22 inches in diameter carries water to city pumps on the shore of Lake Merced in San Francisco. The city pumping station contains two units with a total daily capacity of 7,500,000 gallons, which pump either San Andreas or Lake Merced water into Lake Honda. Central Pump is a single unit with a capacity of 8 million gallons daily, which receives its supply from the end of the Merced branch and forces it to Lake Honda.

The Company is at present engaged upon the construction of a 54-inch lock bar pipe 58,000 feet long from San Andreas reservoir to Lake Honda in San Francisco. This line when completed in July of this year will add 30 million gallons daily to the present 50 million gallon daily transmission capacity. Due to the small loss of head in the line its capacity can be greatly increased at a comparatively small power cost by the installation of a booster pump in the pipe. The new pipe taps San Andreas by means of a tunnel 920 feet long, entering the reservoir 46 feet below the surface.

Crystal Springs reservoir at elevation 288 feet delivers its supply through a 44-inch pipe 89,500 feet long to University Mound reservoir in the southeast quarter of San Francisco. An electrically-operated pumping station at Crystal Springs dam can be used to pump the water through the pipeline when the demand is greater than can be met by the ordinary gravity flow. This station also contains a second unit which is used to pump Crystal Springs water to San Andreas whenever necessary, through a wood flume 29,300 feet long built along the east slope of the valley occupied by the reservoirs. At Millbrae a 10,000,000-gallon pump is so arranged as to take water from the Crystal Springs line and force it into the pipe carrying the San Andreas water to San Francisco.

Water from the three sources of supply in the Alameda system, namely, Livermore and Sunol Valleys, and Calaveras reservoir, is united at Sunol and carried through the same transmission system. The infiltration system consisting of 8985 feet of rectangular tunnels with concrete tops and concrete-lined sides pierced with numerous 2-inch pipes, fed by 2725 feet of auxiliary perforated concrete pipe 36 inches in diameter, with open joints, collects the supply from the water-filled gravels. The collecting system is below the surface of the ground water which is maintained by Sunol dam, a concrete structure about 28 feet high at the valley outlet.

FIG. 4. CRYSTAL SPRINGS DAM

The Calaveras supply is discharged from the reservoir through a 48-inch pipe laid in an outlet tunnel which pierces the west abutement of the dam. The water is allowed to flow down Calaveras Creek to Sunol, where it percolates through the gravels into the infiltration system.

The well supply from the Livermore Valley is abstracted from the underground gravels by pumps and discharged into a 30-inch pipe 28,000 feet long, which carries it to Sunol and delivers it into the main gallery of the infiltration system at the Water Temple, a structure of classic design which surmounts the basin at the meeting-point of the various sub-sources of the Alameda system.

Beginning at the Water Temple, a concrete conduit below the ground surface carries the supply to Sunol Dam. Passing through the interior of the dam from end to end, the water enters the first of five tunnels having a total length of 14,500 feet, which together with 11,400 feet of concrete conduit form the Sunol Aqueduct. The aqueduct has a total length of 4.9 miles and a capacity of 70 million gallons

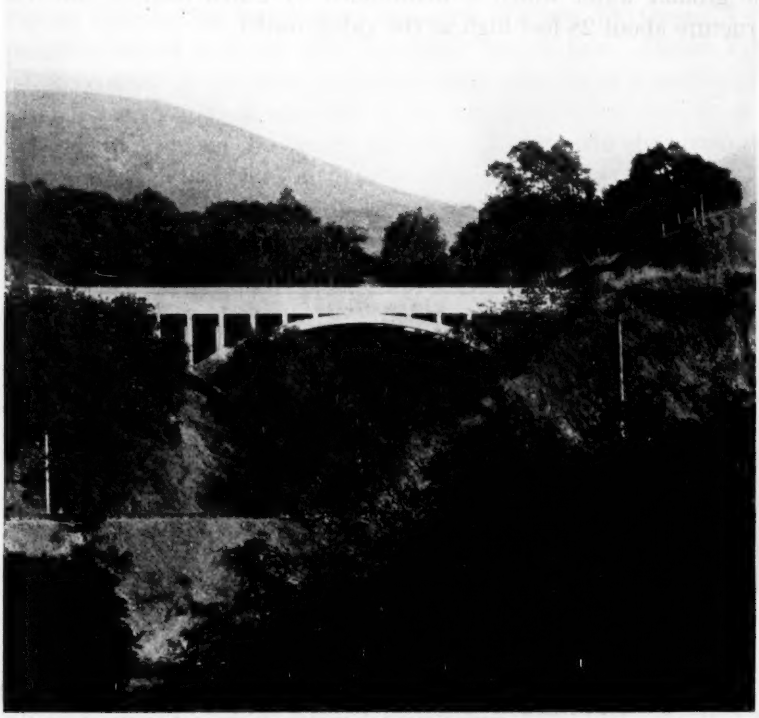

FIG. 5. SUNOL AQUEDUCT

daily. It delivers the water to the Niles regulating reservoir, which has a capacity of 5 million gallons at an elevation of 181 feet. From Niles reservoir two pipe-lines transport the supply on its way to San Francisco. The first is a 36-inch pipe 56,000 feet long which carries part of the supply to Dumbarton Point on San Francisco Bay. The bay is crossed by means of two 16-inch and two 22-inch subma-

rine pipes, each 6,400 feet long. The submarines have flexible joints permitting a movement of 21 degrees from a straight line in order to accommodate the pipe to the uneven floor of the bay. On the west shore of the bay an electrically-operated centrifugal pump forces the water through 51,500 feet of 36-inch pipe to the Belmont pumping station. Belmont pumps, consisting of seven steam-driven units with a capacity of 27 million gallons, force the water through 35,000 feet of 36-inch pipe and 16,700 feet of 54-inch pipe to Millbrae, where the line is connected to the Crystal Springs-University Mound pipe. The second line from Niles reservoir begins with a 44-inch pipe 15,600 feet long which carries the water to a point near Irvington. From there the supply is transported through the Bay Division of the Hetch Hetchy Aqueduct built by the City of San Francisco and used by the Spring Valley Water Company under an agreement with the municipality. The Bay Division Aqueduct begins near Irvington with a 60-inch pipe 48,500 feet long which runs to the east shore of San Francisco Bay at Dumbarton Point. The bay crossing is made with a 42-inch cast-iron flexible-joint pipe for the first half mile. The west end of the submarine pipe terminates in the bottom of a large concrete chamber, which also acts as the end pier for a steel span bridge about 3000 feet long, supported by concrete piers, which carries a 60-inch pipe from the end of the submarine to the west edge of the bay. From the end of the bridge to Crystal Springs reservoir, into which the water is delivered, the line consists of 50,100 feet of 60-inch pipe and a 10-foot tunnel 8700 feet long. An electrically operated pumping station with a daily capacity of 32 million gallons, located near the bay, pumps the water into Crystal Springs reservoir.

The distributing system in San Francisco is necessarily complicated owing to the uneven topography of the City. San Franciso is essentially a city of hills. Covering an area of 46½ square miles, it ranges in elevation from sea-level to over 900 feet. The hills do not rise gradually in easy slopes, but are abrupt and occur irregularly. Consequently the distributing-pipe system is divided by closed gate valves into a large number of major and minor areas in order to avoid excessive pressure variations. A large amount of pumping is necessary after the water reaches the city. In 1927, 49.6 per cent of the consumption was pumped. The total installed pumpage capacity of the system is 187,000,000 gallons daily, 35,000,000 of it in San Francisco. In all there are 18 separate service districts in San Francisco, of which 6 might be termed major districts the remainder being

comparatively small areas which receive their supplies for the most part through automatic electrically-operated pumps, supplied directly from the principal districts.

The lowest pressure zone, the University Mound district, received its supply by gravity from University Mound reservoir, with a capacity of 59,400,000 gallons at elevation 172 feet. This district comprises in general the waterfront, industrial and principal business areas, together with some domestic consumers in the east and north sections of the city. College Hill reservoir, with a capacity of 13,500,000 at elevation 255 feet, supplies the next higher zone. Lake Honda, with a capacity of 44 million gallons, situated near the geographical center of the city at elevation 370 feet, supplies the greater part of the domestic use. In addition to the water pumped into this reservoir from the Merced branch of the San Andreas line and Lake Merced, it receives the surplus pumpage from Clarendon pumps, as well as the entire pumpage from Precita Valley pumps, an electrically-driven unit of 3,300,000 gallons capacity which takes its supply from the University Mound distributing system. The next higher district is Presidio Heights, comprising the top of the ridge running along the north edge of the city. Water is pumped to Presidio Heights tank with a capacity of 700,000 gallons at elevation 400 feet, from Black Point station, containing two steam-driven units with a total capacity of 6,500,000 gallons daily. This station pumps directly out of the University Mound pipe system. Lombard Street reservoir supplies a district on the intermediate slopes of Russian and Telegraph hills. It is a subsidiary of Lake Honda, and receives its supply by gravity from the Lake Honda distributing system. Stanford Heights reservoir at elevation 614 feet has a capacity of 5 million gallons, and work has been commenced on the second 5 million gallon unit. It is supplied by Clarendon pumps, consisting of two steam-operated units with a total daily capacity of 2,600,000 gallons, which draw water from the University Mound system. The district supplied by this reservoir lies on the upper slopes of the Twin Peaks hills. The highest service in the city is Forest Hill with storage at elevation 800 feet.

In connection with the completion in July of the new pipe line into Lake Honda a rearrangement of the distributing system will be necessary. The Presidio Heights district will be supplied from Stanford Heights through pressure reducing valves, and the Black Point pumping station which has been in continuous operation since 1858

will be discontinued. Two steam turbine operated centrifugal pumps are ordered for installation at the Central Pumping station, each of which will pump 9 million gallons daily to Stanford Heights reservoir, receiving their supply either from the new line or the existing Merced branch of the existing San Andreas line.

Although ownership of the drainage areas affords a practical protection to the water, as a further insurance the supply is disinfected.

Chlorination plants are operated at the outlets of all sources of supply and emergency units are located at the principal city reservoirs. Filtration has not been used as yet. The principal sources of trouble in sanitation have been some of the city distributing reservoirs where sea gulls, which are protected by State Game laws, made a practice of spending part of their time. All ordinary means failed to control this nuisance until finally wires were strung across the surface of the water at intervals of about 40 or 50 feet each way and about 3 to 5 feet above the surface. For some unknown reason these birds will not fly down into a reservoir protected in this manner.

Copper sulphate treatment of the catchment reservoirs is found to be necessary every year to control algae, although one treatment is usually sufficient. The proportions used vary from 1 to 5 million to 1 to 8 million.

After seventy years of activity the corporate existence of the Spring Valley Water Company as a purveyor of water will terminate in the near future. On May 1, 1928, bonds to the extent of $41,000,000 were voted by the citizens of San Francisco for the purchase of the water system, and as soon as the necessary steps can be taken the Company's water properties will be turned over to the municipal authorities to be combined with the Hetch Hetchy development.

THE MANAGEMENT OF WATER WORKS BUSINESS[1]

By George H. Fenkell[2]

The management of a water plant is confronted with the engineering problem of furnishing an abundant supply of water for domestic, commercial and manufacturing purposes. To meet the requirements of each class of customers, it is necessary that the supply be free from water borne disease germs, turbidity and mineral content injurious to boilers or manufactured products; that the pressures be adequate and continuous; and that the quantity available at every point be sufficient for ordinary as well as for fire prevention purposes. For each endeavor there is a resulting cost, and in the waterworks business these are divided among capital costs, and charges for operation and maintenance. To insure the continued success of the undertaking, it is further necessary that the expenditures under each of these items be made as low as is possible and still comply with the principles of good engineering.

For the purpose of this discussion the business affairs of a water department, therefore, may be divided as follows: (*a*) The securing of funds at a low interest charge for capital investments, (*b*) the securing of funds for operation and maintenance, including depreciation, and (*c*) to meet fixed charges. To these should be added (*d*) the collection of engineering data and the maintenance of engineering and other records which can be used later as an aid in directing the work of the department.

With the foregoing in mind, it is believed that it is fair to state that the business of a waterworks department consists in securing and disbursing the funds above mentioned and in the ways outlined, and in doing this in a manner that will meet the approval of at least a considerable share of the residents of the community.

[1] Presented before the Plant Management and Operation Division, San Francisco Convention, June 14, 1928.

[2] General Manager and Chief Engineer, Department of Water Supply, Detroit, Mich.

PERSONNEL

The first essential element in a successful waterworks department is in the employment of a staff of competent workers. The management of a privately operated plant is usually free in the selection of employees, and in the establishment of the salaries that will be paid, but in many municipally operated water works but little attention has been given to the qualifications of the applicant when filling a position. Through the operation of a Civil Service department having adequate legal authority, and administered by business men who have had experience in employment affairs, it is possible to remove to a considerable extent the difficulties that prevail when employment is used as reward for political services rendered. The establishment of the Civil Service system, based primarily on the prevention of interference for political or religious reasons in the filling of positions and in making promotions and demotions, marks an important step in promoting efficiency in a municipal water department. The spirit of common devotion will also be improved through the adoption of a system of old age pensions for employees.

A second subject of primary importance is the maintenance of an engineering force that will allow the design for extensions and improvements to be made well in advance of the time that these will be needed in operation. The weakest part of many municipal water projects is the engineering staff that is available for design. When a structure is needed that will require three years to build, with the work carried on in an orderly way, and which can be completed in one year as a rush order, it may be expected that there will be a saving of 25 per cent or more, through the use of more leisurely methods, because the additional time will allow the development of better design, the material can be purchased to better advantage, and labor can be directed in a more economical manner. Even in a well organized department it may be found impossible to solve each problem that arises in a satisfactory manner, and hence the employment of a consulting engineer or waterworks specialist will not only become desirable but necessary, if the best results are to be obtained.

The framers of a city charter do not usually contemplate its use as the basis of control for the formation of an organization and for the operation of a construction bureau to carry through to completion projects of exceptional magnitude. Many city charters, however, contain a provision which requires that a contract shall be awarded

to the "lowest responsible bidder." The operation of this clause has been objected to by many engineers, but, when all things are considered, the writer believes that this is a safe method of procedure to be followed by a municipality.

CENTRAL PURCHASING

Through the use of a department or bureau of Purchases and Supplies it will frequently be found possible to effect substantial savings in the purchases of material. The director or officer in charge of this department has no sinecure. A disadvantage results from centralized purchasing of supplies because of the tendency that it produces for the engineers in the staff of the water department to become less well informed as to what material and equipment can be made available for use, but the gain through the use of such a department is much greater than the loss that it occasions. Many kinds of supplies that are used in a water department are of a bulky nature, but if purchases are made in quantity, and if advantage is taken of the low prices that prevail at those times when the manufacturers are eager for orders, substantial savings may be effected, provided adequate and well located storage space has been developed.

Many well built waterworks structures will be long lived; that is, these may be expected to continue in service for from 50 to 100 years or longer, and some of these at least will be abandoned or razed because of obsolescence rather than because of the effect of wear and tear. The municipally owned plant, because of this, has an advantage over the privately owned plant that operates under a limited franchise, for it can build more substantially.

CHARGES FOR WATER SERVICE

The principal source of revenue for the municipal waterworks department will come from the sale of water; and the charges for water service may be based on measurement by meters, upon rates based upon the number and type of fixtures used, upon rental value of the property served, or a combination of two or more of these. The use of rental value as a measure in determining charges for water is used but seldom if at all in the United States. The use of meters has increased rapidly in the last few years, and while some cities still continue to make collections according to the flat rate or assessment system, the fact remains that many communities are adopting the meter system as the most equitable for the consumers as well as

to the works, and of those that have adopted this method for determining charges, not one, as far as the writer knows, has returned to the flat rate system after meters have once been placed in use. While the cost of operating a meter system may be as great as one without meters, it will usually be found that through the use of meters capital investments are reduced and water service improved. As the filtration of water increases its cost and its value, the installation of filtration plants tends strongly to bring about the early metering of the services supplied.

Methods other than by the use of meters are available for use for the reduction of waste and for determining the plans that should be used for strengthening a water system. Among those that are easy to employ are: (*a*) measurement of the supply through the use of Venturi meters; (*b*) leak surveys by water taken from hydrants and used to feed one block at a time through a hose line; (*c*) pitometer leak surveys; (*d*) surveys of the flow in large mains by the use of pitometers; (*e*) hydrant surveys to determine the amount of water available for the fire department at any point; and (*f*) the use of a number of pressure gauges read hourly and located at several points in the distribution system.

No water department is so small that it does not need to have at least one emergency crew that can respond promptly when a break in a main occurs, for the broken main is the bane of the waterworks management. It usually occurs without warning and without previous knowledge of the time or place where it will occur, and unfortunately the cause for the trouble can seldom be determined later. To maintain men in idleness, subject to call at all times but seldom responding to emergency calls, is uneconomical and will cause their undoing. A plan that has proven satisfactory in some cities is to divide the work of the garage crew into three shifts, to use the garage as an emergency station and the auto repairmen and washers as emergency men for use only at those times when serious trouble occurs.

During the past few years there has been a marked increase in the cost of labor and material, but through economies that have been effected by efficient management it has not usually been necessary to increase water rates in the same proportion. However, there has been a considerable increase in the cost of producing water, and this should be reflected through an increase in water rates in order that the proper balance between capital and income may be maintained. This in-

come should be sufficient to allow the department to operate well, to maintain it in good condition, to pay off annually at least a part of the outstanding debts, to meet the interest when it becomes due and the financial requirements of the sinking fund.

There is a great difference in practice in the methods employed in the determination of the water rates in the different cities where meters are used. Some cities charge a uniform rate regardless of whether the quantity furnished is large or small, usually with a minimum charge. When the municipality owns the meters, a meter rental is also frequently charged. Some cities have a variable rate, depending upon the amount of water used by the consumer, and the use of a three step rate is increasing. Service charges which will cover all or part of the unvarying expenses of water service are coming into more general use, as it is believed that this plan is fundamentally more just to the works and to the consumer.

In addition to the funds that will be secured through the sale of water, additional amounts may be obtained through an assessment against the abutting property for the construction of the distribution mains. Collections through this assessment method have not been generally employed, for some cities lack the necessary authority to make such assessments, and in others because of the slow growth of the system, the establishment of such a method for the securing of additional revenue is not justified. This plan for collecting a part of the cost for extensions is recognized as a reasonable one, and the funds that are collected are of substantial assistance in the financing of new projects.

CHARGES FOR MUNICIPAL WATER USES

In the collection of income tax from employees of municipal plants, the United States Government has assumed that the function of the water department is proprietary rather than governmental. If the Treasury Department is correct in its ruling and the function of such a water department is proprietary, then it should collect from the city it serves its regular charges for all services rendered the municipality. This would include charges for fire service, for water furnished parks, fountains, municipal buildings, for street sprinkling and flushing, and for charitable institutions of all kinds. The department in turn would be expected to pay taxes the same as any private utility. It has been assumed by many that the free service rendered a municipality is offset in the department by freedom from taxation. It should

be remembered, however, that there is a difference between the taxpayers and the water consumers, and further, that water service that is rendered free is used with but little attempt to control its use and to reduce its waste.

The management of a privately owned water plant is concerned principally in maintaining the value of the property and in the payment of dividends. The management of a municipal plant is concerned with developing and operating the plant in the way that will best satisfy the citizens and water consumers and in turning back to the plant for capital investments the surplus which is the result of the economies effected through efficient operation.

PRIVATE AND PUBLIC OWNERSHIP

As the greater number of the water plants in the United States are owned and operated by the municipalities that they serve, it may be inferred that inherent advantages are obtained by serving a community through a municipal department rather than by a privately owned company. While there is no intention to discuss here the complicated problem of private vs. public ownership, the writer ventures to point out some of the advantages of each that affect the business of the departments.

Private management allows: (*a*) better control of employees; (*b*) the payment of salaries somewhat commensurate with the work performed, and hence the employment of those more nearly suited to fill important positions; and (*c*) prompter action for meeting new conditions of service.

The municipally operated department can: (*a*) secure funds at a low rate of interest; (*b*) operate with expenses for legal services and for litigation reduced to a minimum; and (*c*) build structures of a more permanent nature than would be possible for a company to construct that operates under a limited franchise.

There is no single item by which the management of the municipal plant can be judged. The business affairs of a water department differ from those of other public utilities and nearly every other kind of business, in that there are few new purposes for which water can be used. By way of illustration, reference may be made to electric light and power companies, and the gas companies, which have extended the use of their products into fields that were quite foreign to them a short time ago. A few years ago hydraulic elevators and water driven washing machines came into limited use, but the amount

of water used for these purposes now is very small. The cooling of the air in retail stores and theatres through the use of appliances requiring cooling water has been used to a limited extent, but with all of the methods that use water in new ways the amount required is almost negligible.

As a water department usually has a monopoly in the community which it serves, and as the new uses for its product are few, it does little advertising and maintains no sales department. In this respect it also differs from nearly every other kind of business. It is essential, however, that the department maintain the good will of the consumers, and the only channels open for doing this are through the maintenance of the visible portions of the plant in a sightly condition, the rendering of good service and the publicity of its aims and endeavors. The reputation that the department enjoys will be no less due to the promptness and courtesy of employees and the speedy adjustment of its accounts and complaints, than to the excellence of its mechanical equipment and the adequacy of its supply of a wholesome product.

RECORDS

There is little use in collecting and summarizing data unless some good use is made of them after they are collected. The records in the department are collected, preserved and summarized: (*a*) to make possible the prompt collection of all the monies due the department; (*b*) to determine when payments must be made and the amount of the bills that must be met, and to pay all bills when due; (*c*) to keep down the cost of plant operation and maintenance, and (*d*) to determine the future needs of the department in such a manner that the construction requirements will be met in the best and cheapest manner.

RAISING OF FUNDS

Many cities find difficulty in securing funds needed for essential improvements through the limitation established by law or otherwise. However, owing to the elemental need of an adequate supply of wholesome water, laws regulating the finances of a city are usually less restrictive with the financing of water projects than for other improvements. Principally because of this difficulty in securing funds, consideration has been given recently to the proposal that the portion of the sewer system that is concerned principally with the dry weather flow be financed and administered by the municipal

water works. To what extent the sewer system would be so financed and operated would depend upon legal and financial restrictions of the communities in question, and also on local usage and municipal laws. With some, the entire sewer system would be included, while in others storm water sewers would be excluded. Whether or not sewage treatment works would be included would depend upon local circumstances. In the establishment of tax rates, as well as the rates to be charged by public service corporations, the word "equitable" is used freely and without a realization that "ability to pay" is often the deciding factor. As the sewers that carry away the dry weather flow operate in conjunction with and are a necessary supplement to the water system, and as most of the water supplied is removed through these sewers, and as the demand for sewer capacity is in almost a direct ratio to the amount of water used by the consumer, it appears reasonable that administration of the affairs of the sewer system can, in some cases at least, be joined with that of the water department. Objections to the adoption of such a plan would probably be raised by railroad companies which use large quantities of water for locomotive boilers, and by some others, but the number of these would be relatively few. While no general rules on this subject can be stated now, it seems quite certain that within the next few years this method of financing and operating sewerage systems will be given increasing consideration by the governing bodies in many cities.

A well operated water plant is a great asset to a community for a number of reasons that are apparent and which should be appreciated by the consumers. Its effect in accomplishing a reduction in fire insurance rates, or in maintaining low rates already established, is at present generally intangible. It is to be regretted that the fire insurance companies have not found it convenient to evaluate improvements needed for fire prevention purposes.

Excepting those that have given the subject careful consideration, few realize to what an extent the demand for fire protection service influences the design and cost of a waterworks system.

Experience has shown that the cost of the portion of the waterworks involved by fire protection service in this country generally constitutes from 60 to 80 per cent of the entire cost of the physical property in the case of commmunities having less than 10,000 population; 30 to 40 per cent in communities of about 50,000 population; 20 to 30 per cent in communities of about 100,000 population; and 10 to 20 per cent in the case of our largest cities.[3]

[3] Manual of Water Works Practice, page 593.

Finally, the prosperity and growth of a city will continue to be contingent to no small degree on the excellence of the water works system and the reasonableness of its water rates. In the coming years it will be found that, to maintain the works at a high degree of efficiency and to furnish water at rates that are consistent with the capital costs and other expenses involved, the ingenuity of the water-works management will be taxed to an ever increasing degree.

DISCUSSION

Charles S. Denman:[4] Mr. Fenkell's paper is intensely interesting and touches on vital points of the success of any business, whether public or private.

There are several important subjects referred to that it would be profitable to discuss, such as civil service, old age pensions, employment of competent consulting engineers, letting of contracts to the lowest bidder, purchase of materials, maintenance of sinking fund investments, taxing of extensions to abutting property, income taxes, economies in plant operation, publicity, etc. All of these are very important, but I shall limit my discussion to but one subject which he has brought out.

The most essential utility in any city is the water plant and its management should be a mere matter of business just as any other legitimate business. The first consideration is to give the community an adequate supply of water, safe from a health standpoint and satisfactory for industrial uses. This service should be furnished at the lowest reasonable cost to be given under competent and economical management and should not be done at a loss. It is just as improper for a city to run its water works at a loss as it is to expect any private business to do so.

There has been wonderful progress made in the betterment of water works practice, along lines of engineering, improvement in machinery and boiler room practice and in the purification of water supplies. It was not long ago that many cities did not furnish clean water. "Like the pestilence that walketh in darkness" typhoid and water-borne diseases were prevalent. A toll of innumerable lives was unnecessarily sacrificed through ignorance, which has now been largely eliminated.

In many instances, however, little or no progress has been made

[4] General Manager, Des Moines Water Company, Des Moines, Ia.

towards bettering the business management of water plants. We should give a good account of our stewardship to the community. It not only tends to uphold us but it improves their morals as well. Running a water works in a city is a complex business and requires the same skill and careful management as any other large business industry.

The chief bane of all public business is politics in its abased sense. The better and nobler meaning of the word is the protection of our citizens in their rights, with the preservation of their morals and signifies the highest sense of civic duty, the largest effort for the good of all and the most rigid exclusion of everything that is base and mean. Too often water plants are looked upon as legitimate prey by persons who wish to use them to further selfish and dishonorable ends. Unnecessary and wasteful expenditures would thus be made. The same careful attention, sagacity and sound economic principles in making purchases, as are shown in private business, should be practiced. Purchases and contracts should not be made to pay political obligations. The manager often has no direction over the purchase of equipment and materials, employment of his assistants and labor, or the manner in which his books are kept. In some cities no inventories or valuation of property are made, no depreciation is taken into account, and no cost records are kept. Political management encourages granting of special favors and is destructive of business activity, discourages energy, removes incentive to new enterprises and produces other attendant evils. There is too much wasteful and unscientific management.

The sad results of political rule are appallingly apparent in our cities and should not be tolerated in any civilized country. I have no particular cities in mind. For example, we can do much to increase the efficiency of our plants and reduce the costs of production and distribution not by cutting wages, but by better management. We thus reduce the costs to our consumers and yet are enabled to pay higher wages to more efficient employees.

Our business is one without competition which may sometimes have the effect of removing incentive for the most economical management. All publicly owned plants get through because they have no competition and except for that and the enormous taxing power upon which they can fall back where they are able to make the public pay for their losses and for their mistakes some of them would have been in bankruptcy. The idea that deficits of operation can be

absorbed or hidden in taxes is a mistake. Rates are often reduced in proportion as taxes are increased. This is like keeping a dog alive by feeding him with pieces of his tail. Service that does not pay its cost must depreciate, slow down and ultimately stop if carried on to the end. If, due to wastefulness and bad management, we are doubling our cost of production it is a disgrace. We are doing an injustice to our people and committing an immoral act.

We must revolutionize our economic, financial, managerial and operating principles and practices, not only in our water works, but in handling all public business. The highest motives in our business are those of the engineers, because such men are creative and more ethical. Many inconceivable and perfectly disgusting instances, that are not found in any code of morality, might be cited. The best that could be said was that they were round about and more or less in the twilight.

Good business management is fundamental to success in any business and is dependent entirely on scientific management. The manager should be trained and experienced in his line of work, a man of character, which means honesty and unimpeachable integrity, and should have common sense, self-sufficient in the matter of certain essentials to proper administration with no plan except for constructive policies. He is the connecting link between the public and the working force and should not be politically menacled and should be paid on a basis comparable with other lines of business. To employ cheap men in high places is fatal; no business can grow and prosper under such conditions. He should be paid the market price or better. Investments in high class men pay better than any other investment. Give the manager the assurance of continuity and that except for cause his position is permanent. He should have a board of directors composed of the leading men of the city, independent and permanently appointed except for improper practices. There is too much pretense that one man is as good as another when it comes to handling public business and no need for training and experience, or need to develop business experts in our line of business, or that the control should be by expert administrative boards. The manager should be given a free hand. There should be no divided authority. He should be allowed to select his assistants and employees without political or other interference, thus enabling him to obtain the most loyal service and coöperation on the part of his co-workers instead of an attitude on the part of such workers of simply trying to get by. Employees,

willing to do more than they are expected to do, increase their independence and bring a sure reward.

It has become a hackneyed expression that business honesty must be practiced and from the point of expediency alone there can be no other principle. The basis of all business is confidence and when that is destroyed there is nothing left. We must be honest or we shall surely fail. It cannot be otherwise or else neither government or business can exist. Men do not "gather grapes of thorns or figs of thistles." Honesty must be made an abiding principle for it is the first consideration to success. With these fundamentals to success we must have thoroughness in business which means making the most of what we do in all things and without being cranks must observe good habits of which, aside from a moral standpoint, there are no set rules—but should be approached from the hard common sense viewpoint of temperance which means moderation.

Some constructive policy should be outlined for better management of public business and a program effected to bring it about by a campaign of education. It may be slow but much can be accomplished by education. The public must be educated to know and understand that as now constituted there can be no effective management when the heart is taken out of those who conduct public business. All unwise restrictions which interfere with individual initiative must be removed. There is a legend which says "There is no mistake so deadly as to do nothing when things go wrong." There must be a determination that our business shall be non-partisan and non-political. Public opinion must be with us. It's a hard thing for a man to go against public opinion. People do not respect a person who has lost the respect of others. We should pledge ourselves to insist on a policy of efficiency and economy in the conduct of the business of our water works and join in some unified plan to divorce them absolutely from all political entanglements, remembering that it is exclusively a business proposition, that we may give to our cities as good if not better service than is furnished by any private utility.

The time will come when through education the people will see the wisdom, the justice and the intelligent self interest of placing all public business on the same sound foundation as is any other well conducted business. Progress in this direction has been made and will continue. Much pressure for better conduct of public business is now being brought on political parties, although it is now more of a resource than a reality and more of a possibility than a fact. It some-

times takes a long while to break down evil practices in public affairs, but it has been done and it can be done.

Howard S. Morse:[5] With one exception I find that my views harmonize with those expressed by Mr. Fenkell in his paper.

This exception is with reference to the twice made statement that a municipally owned water department can build structures of a more permanent nature than those built in a privately owned plant. Mr. Fenkell does not assert that this is the practice, but this is the implication. My observations do not confirm this suggestion.

The Indianapolis Water Company, for example, has no franchise but operates under an indeterminate permit from the Indiana Public Service Commission. But I am not aware that this fact influences in any way the type, extent or substantiality of its construction projects.

It is true that the management of this Company, in common with all other privately owned water plants, "is concerned in maintaining the value of the property and in the payment of dividends." However, it is none the less concerned in "developing and operating the plant in a way that will best satisfy the citizens and the water consumers."

Maintaining the value of the property does not mean to us maintaining a fictitious or inflated value but real value inherent in adequate, substantial structures in first class operating condition. Further, the management of a privately owned water plant is keenly alive to the necessity of satisfied customers from business rather than political reasons. If a privately owned water plant subordinates service to customers to the obtaining of dividends, it is time for municipal ownership. But I submit that the proper way to secure dividends is through efficient management with fair rates for the service rendered.

Judge Joseph W. Ulman of Circuit Court No. 2, Baltimore, Md., in Opinion rendered May 10, 1928 in a case involving United Railways & Electric Co. and a ten cent fare said, "that the higher fare is reasonable from the public standpoint was shown by the fact that it was practically equivalent to a five cent fare in 1913." This is a simple statement of fact, the truth of which seems to be studiously avoided in the consideration of rate questions.

[5] General Manager, Indianapolis Water Company, Indianapolis, Ind.

Therefore, Mr. Fenkell's comments on increase in cost of labor and material, and the consequent necessity for increases in water rates, are timely and to the point. With due allowance for the influence of ward politicians and demagogues, it may be said that in general the public is reasonable, wishes first class service and expects to pay a fair price for such service. Good management recognizes this fact and does not dodge the question of rates, no matter how difficult or unpleasant it may be.

Rates should be commensurate with the service rendered. This involves not only the obtaining of a total revenue sufficient to make the property truly self-supporting, but the rate structure should be erected upon an economic rather than political foundation. The rates for different classes of customers should be balanced with the cost of these services.

Also, while water plants are generally assumed to be monopolies, in fact many face very definite competition in the way of private wells, both domestic and industrial. Good management will not neglect this condition, but for the old "wait for the customer" attitude will substitute a definite sales policy.

Although the managements of municipally owned water plants are not concerned with dividends, my experience in both privately and publicly owned plants prompts me to suggest that the municipal plant manager can with advantage devote more attention to the financial and commercial side of management, especially with respect to rates, costs and development of business, than is frequently the case.

Joseph E. Mills:[6] The very excellent paper on, "The Management of the Water Works Business" states very true facts in every case, and is an exceedingly interesting and valuable document.

I wish to comment on one factor, only, namely, the purchasing of materials, supplies, and equipment for the water division. The purchasing of materials and supplies is a profession. No longer can a purchaser function purely as a clearing house for requisitions in the old order of events by merely placing an order with some company.

The purchaser must first be an economist, with his integrity beyond question. He must devote a great deal of time to the study of economics as it pertains to business conditions, not only in this country,

[6] Purchasing Commissioner, Department of Water Supply, Detroit, Mich.

but abroad. He must analyze, and attempt to determine influences that will effect the supply of materials, such as, cast iron pipe, lead, etc., for the water division, as the amount of money involved in supplying a water division with materials is very large.

The purchaser must necessarily advise the water division relative to market conditions, and, in so doing, must work very closely, and coöperate to the fullest degree, and be conversant with present and future construction programs of the division.

Both departments must, naturally, fully understand the general conditions that exist in each division. First, the purchaser must understand that emergency items must be considered as real emergency items, and expedite delivery in every way of any materials needed due to breaks or other unlooked for trouble. A purchase of this nature cannot go through the usual procedure, but must he handled directly, in the shortest, quickest, and most efficient manner.

The water division must understand and respect the legal conditions surrounding the public purchasing of materials, as the legal requirements, naturally, consume more time than that utilized in the purchase of like quantities of material in private business.

The purchasing division must be absolutely divorced from the political situation, if it is to function in a fair and impartial manner. Only in the divorcement of the department from political influences can confidence of vendors be deserved, and received, and the resultant competition and low prices be taken advantage of.

Theodore A. Leisen:[7] The paper by George H. Fenkell enumerates a number of facts, virtually axiomatic and so self evident as to leave scant opportunity for criticism or discussion, unless that discussion, as too frequently happens, resolves itself into a reiteration of what the paper previously had stated.

Briefly summarized, good management of a water works, in its broadest sense, consists of providing the best and most efficient service in a resonably economical manner, without resorting to parsimony.

The management of a water works business differs from that of most other classes of industry, particularly in regard to quality, quantity and service to the public, in that the water department must strive for the very highest standard of excellence attainable, regardless of cost, as the public is justly entitled to the best that can be pro-

[7] General Manager, Metropolitan Utilities District, Omaha, Nebraska.

duced, both from the viewpoint of sanitation and personal comfort, and the management is responsible, directly and indirectly, for such results.

Most other industries are not so restricted. They may produce a Rolls-Royce or a Ford; a high priced product or a cheaper and less desirable substitute. In either case they meet the requirements of their particular field of endeavor, and no criticism attaches to the management furnishing the cheaper article, but the water works manager cannot afford to fall below the Rolls-Royce standard. Then, too, the managements of most other industries are able to shift a large share of responsibility to the shoulders of their agents, their retailer or distributors and other subdivisions of the business. The water works manager must assume the whole responsibility.

In saying that a high standard must be maintained regardless of cost, it must not be understood that extravagance is invited, for it is seldom that extravagance produces good results. The very spirit which induces a manager to strive for economy in operation, will insure his attainment of efficiency. A million dollars wisely and properly expended to filter a contaminated water supply is economy; the retention of two or more employees to do one man's work, or the consumption of two tons of coal where one ton under proper operation would do the work, is rank extravagance, and the efficient manager will not tolerate these latter conditions.

Epitomizing the essence of this discussion, the writer desires to emphasize, in addition to what has been so well covered in the original paper, that efficiency and economy in operation, courtesy and service to the public, and the highest standard of quality of water supplied, are the essential factors for which the water works manager must hold himself responsible.

Caleb Mills Saville:[8] Mr. Fenkell has presented a most interesting and orderly summary of the chief duties devolving on the management of a municipal water department.

This paper could have continued almost indefinitely without duplicating description of the many functions comprised under the subject. The author, from his broad experience, has delivered in concise statements information which should be of value to water department executives in presenting opinions and recommendations to

[8] General Manager and Chief Engineer, Department of Water Supply, Hartford, Conn.

those in whom the final decision ordinarily lies regardless of their knowledge or acquaintance with the detail of water works management.

As would be expected from the author's training, he stresses the broad engineering aspects of his subject without dropping into the detail of furnishing "an abundant supply of water for domestic, commercial and manufacturing purposes" which is the first and last duty of a municipal water department. For privately operated works duty to share holders is a prime requisite which often outweighs all others.

Safe water under adequate and continuous pressure is of the very essence of the water supply requirement, but following these closely come those accompanying duties of management the successful accomplishment of which makes for efficient service. The author rightly places the employment of a staff of competent workers as the first essential element in successful operation, whether it be water works or any other employment. The modern bricks of efficient and economical production require competent assistance as well as those ancient ones which could not be made without straw.

The bane of public utility service is the demand for place rather than the requirement of production. Undoubtedly civil service will and has helped considerably in removing annoyances from a public executive, but there are so many accompaniments to its operation, that it is far from being a panacea for the ills of public employment. Old age pension for employees is a considerable step in obtaining efficient operation. Although it sounds well to speak of "the spirit of common devotion" engendered by this means, the best result obtained by it is the opportunity to properly replace old and faithful employees by other younger and more physically able without hardship to the older ones.

One of the essentials of the successful executive is "vision," the grasp of necessities long before their actual appearance. In order to meet future conditions and be ready for them, plans must be made and work accomplished. To do this requires a trained and skillful force. The neglect or inability to have such an organization is too often the concomitant of public service and is not always absent from that under private control.

The employment of consultants for special work is more than a desirability; it is a necessity for proper working out of the great problems that confront public works today. No man today is ex-

pert in all lines, and advice of a "Jack at all trades" is usually worth what is paid for.

Much may be said of the purchase of supplies and materials by a common department, but here, as in other walks of municipal endeavor, it is a palliative not a cure, and is often a matter of expediency rather than a method fully to be desired.

Often, undoubtedly, considerable savings can be had by quantitative purchases, but on the other hand it has frequently been observed that the purchasing department is more concerned with economies than with quality, and uninformed buyers are a serious handicap to efficient progress.

The discussion of meters and their installation is along the lines of best modern thought, and contrary argument is based either on ignorance or ulterior purpose. The author lists methods which supplement the use of meters, in controlling waste and strengthening the supply service. It seems desirable to add to these the utilization of the services of specialists in these departments of water supply activity, especially for those works which do not maintain an efficient staff for this purpose. It is an excellent thing for all municipally operated works to have frequent access to outside advice. In commenting on this subject I call attention to the great benefits that are had by all water works executives from the meetings and close personal touch with others in similar employment, arising from frequent informal conferences among managers of water works in nearby locations. The author well may call attention to the need of emergency crews to respond promptly in case of trouble. The time has passed when a break in a water main can be neglected even for a short period. Too much of value is at stake, both in property, time and inconvenience to citizens, and the modern trend of court decisions is to place the burden on the water department as operator of a proprietory business rather than an agent exercising a municipal function.

That water rates have not generally been increased to meet the increased cost of material and labor is not sound policy, although perhaps it may seem desirable to let the dogs of public criticism sleep if they will. This practise, however, is often due to ill advised expediency or inertia on the part of municipal officials. In most cases if the management of the utility will take the "bull by the horns" and give logical and concise reasons for changes, he will be surprised at the backing he will get.

The matter of sufficiency of income is a moot question. Whether

the "pay as you go" policy or the method of bond issue to meet capital expense is best, is usually considerably dependent on local condition. Generally, income should be sufficient not only to cover all maintenance and operating charges, including interest, sinking fund payments and depreciation of plant, but as well those capital expenses for improvement that are of comparatively short life.

The minimum charge for water service, i.e. a charge that includes water use, has little or no reasonable excuse for being. It is one step only above the old fixture rate charge and at its best is but a compromise to get some return for service, because of objection to the logical method of service charge, plus independent rate for water consumed.

The use of the assessment method for financing main pipe extensions is logical and just in that it takes the burden of expense from existing consumers and places it upon those whose real estate values will be benefited. The give and take methods in municipal operation are to be thoroughly condemned; modern business and utility control deprecate such arrangements. All municipal departments should pay for the service they receive from the water department and that department, whether publicly or privately owned, in turn, should pay its way exactly as would any business enterprise.

Supplementing the author's discussion of the problem of private and municipal ownership, it is of interest to call to attention the recent action of San Francisco in the final purchase of the Spring Valley Water Company system, with the somewhat remarkable expression of the voters in its favor. This action brings into the municipal fold San Francisco and Oakland, two of the largest cities in the country previously dependent on private works for their water supply.

The author calls attention to a radical difference between water utilities and those supplying other needs of the public in his statement of the limiting uses to which water is put and the broadening field open to gas and electric utilities. Perhaps this is a cogent argument in favor of municipal control. If so, the answer lies in reduction of cost of service by more efficient operation and this in turn requires better methods for conducting public business.

The author is essentially correct in his comment on the uselessness of collecting data which are not used, but this is not the fault of the data but the collecting agent. Proper data are always valuable, and their collection, even if not fully used, are not without value. Some time, someone will be more able to comprehend the importance of such records in making the works more useful, or in extensions and

new construction. Records cost comparatively little; later they may be of inestimable value, and if not taken there is no recovery.

As to the combination of water and sewage works, it seems to the writer that these are two distinct operations that well may be kept separate. The fact that few sewage disposal systems, but many water supply systems, have been and are privately operated may be an indication of the desirability for continued separation of these two municipal functions.

There seems not the slightest question that the author's final statement is sound, namely, that the prosperity and growth of the city is contingent upon the excellence of its water supply.

M. M. O'Shaugnessy:[9] The writer has discussed this subject in a very comprehensive manner and adverts to the importance of having a competent engineering staff to design and supervise the works.

I have been City Engineer of San Francisco for the past sixteen years and one of the first subjects discussed with the Mayor James Rolph, Jr., before accepting the position was that of responsibility for the engineering staff. I want to say that he very graciously accepted my suggestions in that respect, so that all the engineering works on the Hetch Hetchy Water Project have not been embarrassed by political applicants. As a result we have a most excellent program of construction and it has been very well designed and constructed. In only two cases in sixteen years did I deem it advisable not to award to the lowest responsible bidder. If that bidder has made a mistake, which clearly indicates his incapacity to do the work, I think it would be a fatal error to award it, and it would be much better policy to reject all the bids and readvertise.

I believe it is a good suggestion that extensions for new mains should be a levy on the front footage of the property served. By this method land speculators with vacant lots will have to pay a charge for the service of the pipe and the funds thus received would be of substantial value in financing the new projects. I believe the City's water business should be kept on a business basis, a proper charge being made for fire service and for water furnished parks, fountains, school and public buildings, street sprinkling and flushing.

San Francisco, by a vote of 4 to 1, on the first day of May 1928, has agreed to purchase the private water company now yielding 48

[9] City Engineer, San Francisco, Calif.

million gallons daily for a price of $41,000,000, including all its reservoirs, pipes, and lands, which embrace about 63,000 acres of land. The principal reason for this was to avoid duplication of pipes and reservoirs for the Hetch Hetchy Water Supply, which would be compulsory if the City had not bought the system.

The City will issue bonds at 4½ per cent, which will sell at about a 4.2 per cent basis. The private water company's bonds carried 5 per cent and their stock 6 per cent interest. So the saving on those two items will amount to over $700,000 a year and will eventually result in a cheaper water supply.

San Francisco is in a very fortunate position with regard to financing, as a Charter amendment was obtained about two years ago, removing the bond limit for water investments. This is an extremely wise measure, as our main source of supply from Hetch Hetchy—470 million gallons daily, is 160 miles from the City and has to date cost $55,000,000 to build and will cost $24,000,000 more to complete. Very fortunately we are getting a power revenue now at Moccasin Creek, from a 100,000 H. P. plant that amounts to $2,000,000 a year from the sale of energy generated by the fall of the water from the conduit, and this helps out materially for the taxpayers.

The City was compelled, after the fire of 1906, to build a high pressure auxiliary fire fighting system, consisting of 74 miles of heavy cast iron mains tested to 300 pounds per square inch, at a cost of about $5,500,000. This is connected by 20-inch cast iron mains with two pressure pumping stations on bedrock near the bay waters, which are kept constantly under steam and ready at an emergency to deliver sea water into the pipes. The City did not consider it wise to place sea water into the pipes, however, and has never indulged in this practice except in cases of urgent necessity. Over $250,000,000 in buildings were destroyed in the fire of 1906 and this substantial battery of pipes and pumps saves us from a repetition of this disaster.

John A. Foulks:[10] Mr. Fenkell has brought out many good points in his paper, but in discussing the subject of "Management of Water Works Business" I will approach the problem differently to attempt to show, without going into details, where the management of plants, especially those under municipal control, can be improved.

Water works business can be divided into two divisions:

1. Operation and maintenance.

[10] Consulting Engineer, Newark, N. J.

2. New projects, major extensions and improvements.

In the operation and maintenance of utilities efficient management is obtained with an organization producing the best results with the least effort and greatest economy. This organization should consist of a well defined plan of operation and a carefully selected personnel to suit the various positions as outlined in the plan.

Frequently the politician who makes a living through politics places his associates at the heads of departments. The appointee may be a lawyer, doctor, or business man; a good organizer, but entirely unqualified for the appointment. The next step taken by the new department head is to make appointments and endeavor to make jobs in the organization to fit his new personnel. This is absolutely foreign to the plan of good organization. Such officials forget that it is the public's business and not theirs. Their positions are more or less temporary and the organization must go on indefinitely. The department heads may influence the results of the organization while they are in office, but to change the whole plan to fit the personnel is deadly.

Successful organizations are built up by a process of addition and elimination, and not by constantly reorganizing which tends to disorganize. The divisions that fail to function, as they should, can be changed gradually, either by correcting the method of procedure, shifting or changing the personnel, or both. These changes should be made only as fast as they can be assimilated without materially affecting the working of the system.

Mr. Fenkell has pointed out that the establishment of Civil Service system marks an important step in promoting efficiency in municipal departments. This is true, and while it is not meant that the Civil Service should direct the work of the various departments, that have men appointed for that purpose, it should have the power to safeguard the interest of the public against unnecessary or unwise expenditure. It seems practical that, if the Civil Service has the power to specify standards and salaries for personnel, as they do in most cases, it should have some authority over the plan of organization. Changes in the plan should not be allowed unless it can be shown that the service will be improved. When men of high standards are placed at the head of Civil Service better public management will be obtained.

In the second part I have divided the engineering personnel into two classes, technical and practical engineers.

New projects, important extensions and improvements should be under the supervision of technical engineers, who in many instances are specialists. It is only the larger systems that can afford to economically carry men of this caliber on their pay-rolls permanently. The most efficient results can be obtained by selecting outside assistance when these projects are contemplated and the work done by contract. In many cases where the smaller plants attempt to do this class of work they disorganize their operating and maintenance forces, which are made up mostly of practical engineers, and the completed work is unsatisfactory. I have known of cases where the entire construction force on new work has been carried on the pay-rolls as maintenance, as it was impossible to lay off the additional force required for the new construction upon its completion, on account of political influence.

Mr. Fenkell has mentioned many other important subjects impossible to discuss at this time, which materially affect the operation and management of water plants, such as metering, water waste surveys, etc.

Those in charge of public affairs are frequently too willing to spend large sums on projects that can be advantageously delayed by more efficient operation of existing plants. The engineer apparently very often forgets that he has to deal with practical politicians. Frequently better results can be obtained if the politician is shown where he can make a material saving and give better service. He has an asset in this case which will more than offset politicial patronage.

James E. Gibson:[11] There are one or two points in Mr. Fenkell's paper to which I should like to refer. One of them, particularly, is that of the Purchasing Department. I am thoroughly in accord with the paper, to the extent that purchasing material should be done at the opportune time, and in the right amount, taking advantage of the market, the same as with a private company.

But in cities a great many times we have a city purchasing agent who is appointed for some reason, usually political, or for service rendered in a political way. His one consideration is purchasing for price. I think that there should be some safeguard placed around the purchase of all materials. Just because the water department

[11] President, American Water Works Association; Manager and Engineer, Water Department, Charleston, S. C.

wants pipe, it does not necessarily follow that the cheapest pipe that can be purchased on the market is the most desirable material for that particular job.

The same way in the supply of chemicals, coals, etc. Today, when the price of coal at the mine is running only 10 to 30 per cent of the cost of freight, it does not pay to buy cheap coal.

Take my case in Charleston. We can buy coal as low as $1.25 a ton at the mine. The lowest freight rate is $3.10. So you cannot afford to buy coal at $1.25 which evaporates six or seven pounds, when you can get a much better coal for $1.75 and get an evaporation of eight, nine or ten pounds, and the freight rate is only $3.30.

In any purchasing department, before the actual purchase is made, the prices should be reported back to the requisitioning department for approval before the purchasing agent actually closes the contract.

L. M. Anderson:[12] I agree entirely, in this regard, with what Mr. Gibson has said. Fortunately, under our city charter in Los Angeles the Department is permitted to employ its own purchasing agent. We found that the city purchasing agent knew how to buy lead pencils, pens and a little stationery, but that was about the extent of his purchasing ability.

So we learned that it was not good for the purchasing department to buy supplies of every nature. For several years, in fact, for a number of years, we have had our own purchasing department, and it has worked very satisfactorily. The purchasing agent in charge is strictly a water works man, more than that now, because we have power too; but he works for the water works purchasing only, and it works very satisfactorily.

James E. Gibson:[11] I might add that we are a small department. Our pumpage runs about 5½ to 6 million gallons a day. Our gross revenue is something like $360,000 a year.

When I first went to Charleston some ten years ago, I found a privately owned plant at the time where there was indiscriminate purchasing. When the superintendent of distribution wanted something, he bought it. If the secretary of our office force wanted something, she bought it—with the result that at the end of the month,

[12] Controller, Department of Water Power, Los Angeles, Calif.

or at the end of the quarter, bills came in from all directions of the compass, and you had to spend half of the next month finding out where this material was used, who had purchased it, and if it was at the proper price.

I put an end to that almost instantly by simply notifying all of our local people that unless they had an official order they were to supply no goods. Of course, that was rather drastic. I have had to modify it somewhat. Now, no material is purchased except through a requisition made upon the office, or unless I am out of the city, or there is urgent need for that material. The requisition passes over my desk. I specify either where it shall be bought or detail someone in the office to buy it.

The exception is, however, in the case of an emergency, such as a break. The foreman in charge is authorized to requisition anything he can find from any source whatever, paying for it either out of his pocket or delivering a written order on the man supplying the material. That, of course, is promptly audited and the party receives pay, with the result that now we have no difficulty in keeping accounts. We know each day what has been ordered and what we owe, and what has been delivered. I must say that we have reduced the cost of repairs and maintenance materially.

There is one thing, however, in a municipally owned plant, that sometimes works against efficient management. If the municipally owned plant begins to show dividends or profits or surplus—whatever you may classify as a gain—the politicians begin to want to use those funds. Notwithstanding the fact that the management may want to reduce rates, it is very often put up to them, "We can not afford to reduce rates. We want that money for something else. We should like to have it for the general sinking fund, or we want to use it for the sewer system,"—or some other just cause, as they see it.

Of course, that is absolutely against sound accounting practice. I believe the decisions of the courts now are coming to recognize that in a number of cases. In Columbus, Ohio, I think it was, they wanted to raise the rates of the department so as to increase, or get a greater fund for the benefit of the fire department. I believe the case went to the Supreme Court of Ohio. The Supreme Court stated that it was illegal to use the funds of the water department for any other municipal department; that if the rates were too high, they should be reduced so the ratepayer or consumer would receive the benefit.

L. MURRAY GRANT:[13] The question of the purchasing agent in the matter of obtaining supplies is acute in all water works departments. We are organized in Seattle along lines under which we have a purchasing agent who is an employee of the Board of Public works. The Board of Public Works consists of six heads of departments, of whom the water superintendent is one. Our charter requires, as many charters do, that purchases be made on advertised calls, and that the business be awarded to the lowest qualified bidder.

When I first went into the water department, about two years ago, after having had experience prior to that time only with privately operated companies, I felt that there was considerable handicap here, in view of the fact that frequently you do not want the cheapest thing that is offered. However, it was a charter requirement, and it had to be met. We have proceeded in the department, in the last few years, to devise ways and means whereby we can get what we want within reasonable means, and still meet this charter requirement.

To speak to two definite points, just as illustrative of what can be done along these lines. I might say that we recently bought a booster pump, a relatively small unit, as our system is basically a gravity system. We bought this pump strictly on a duty basis. In other words, we stated in our call what we wanted to do with it, and we specified that the award would be made on the basis of the complete unit, motor and pump, which would be cheapest, operating 4,000 gallons, at a certain rate, with depreciation fixed at 10 per cent on the bid price.

The outcome rather surprised some of my associates on the Board of Public Works. We bought a unit that cost 50 per cent more than the lowest qualified bidder, and we made a good buy, incidentally.

Another incident of that kind was the meter problem which we all have with us. We are now 100 per cent metered, with 75,000 meters in service. We originated a specification on our last call which is a little different from anything we have done before. We have for sometime used the A. W. W. A. specification as a standard, with some little additional features for purely local purposes.

But on this last call, much to the disgust of some of our friends who wanted to sell us meters—but I am frank to say it met with the approval of the better class of salesmen—we introduced into our call the stipulation that we would not consider as accredited any meter that had not been in our system for over a year and given satisfactory

[13] Superintendent, Water Department, Seattle, Wash.

service. But we also made a proviso, there, that if any meter manufacturer who had a meter which would meet A. W. W. A. specifications cared to submit ten meters for test, we would undertake to put those in service for one year. If at the expiration of that year they were satisfactory to us, they would be accredited. Also, the manufacturer would be paid for those ten meters, at the price at which the last lot was entered or bid, and that in the future that particular meter would be found an accredited meter.

At first we arbitrarily rejected some meters which I would like to have considered. On the other hand, we rejected a lot we did not want to consider.

That is a problem, particularly in the municipally owned plant, that can often be solved along those lines. In other words, it is a problem of specifications. Specifications can be so drawn that the department will be protected, and you will really get competitive buying; at the same time you will get the type of equipment that you need.

William W. Brush:[14] I think Mr. Fenkell in his opening has left out necessary qualifications for water supply to be satisfactory; one item that is universal and that is the quality of palatability, to which attention is constantly directed. I am sure that every consumer is desirous that the supply should be made palatable, even though the expense may be relatively high.

He has left out a second item, which may be all right in his case, but which should never be left out on the eastern and southern coasts, that is, the question of the corrosive effect of the water.

There, again, it is worth a very large sum of money, relatively, to reduce the corrosive effect of water supply on account of the loss, not alone in this municipality in its distribution mains, loss of carrying capacity, but the cost of replacing piping in the home of the householder. Such replacement requires considerable destruction of the interior of the building.

The question of civil service employment is interesting and troublesome.

The effect of pensions on the attitude of the employee is quite interesting. In New York City, where we have a very liberal pension

[14] Vice President, American Water Works Association; Chief Engineer, Department Water Supply, Gas and Electricity, New York, N. Y.

system, the attitude that develops in an employee when he reaches the age at which he can voluntarily retire is striking. The plan usually provides that he would receive a pension of perhaps 50 per cent of his salary, averaged over the preceding five years. He goes around with a chip on his shoulder—even the best of them. His attitude is, "Well, you are paying me about half my salary, because I could retire on half my salary. And if you do not like the way I do my work, well, I can get out at any time."

That is just a human reaction. But it is nevertheless an interesting one, and one that affects somewhat detrimentally the work performed by the employee. When you have a fairly early voluntary retirement age, it means that some of your very good men are adopting that attitude at a very early age. We retire at fifty-five if they wish to.

The central bureau for supplies has been spoken of. I wish to add my belief that the central purchasing department is a very costly mistake in any municipality, where it is either impossible or difficult to maintain the personnel's interest of the purchasing unit in the work to be performed. I believe that the efficiency in a municipal plant is almost directly proportional to the personal interest that is maintained by the employee in the work to be done. When you establish a central purchasing department that covers many different city departments, it has been our experience that that department has virtually no interest in securing supplies promptly and is more interested in its own records and methods than it is in the output from the viewpoint of the consuming department.

I agree with Mr. Grant that there is absolutely no reason why you cannot purchase an entirely satisfactory article and one that you want, even though it be the highest priced article of its kind in the market, if it is necessary and desirable for your particular need. That is wholly a matter of specification. I have never yet found in New York City, where we have very restrictive requirements as to competitive bidding, but that we could specify, and legally specify, what we needed and secure it.

That does not mean that we always do so. But it is because we fail to exercise the necessary advance investigation, usually, that can be made to prepare a suitable specification.

In place of a central purchasing department, what would give to the municipalities the advantage which they should have from centralization in that direction is to have a centralized agency which

would require only a few men, that would draw standard specifications and a set-up of standard methods to be followed by the different departments in carrying on their purchases. There is no object in a dozen different departments in a large community drawing a specification for the same article, and probably not one being as good as the one you can get by combining those half a dozen or more specifications.

That, in my judgment, is the way that a large city, and a fairly moderate sized city, can secure the advantage of centralization in purchase, in the various departments, by working directly under such specifications and plan of securing bids and awarding the contracts or orders.

I shall take just one or two minutes to give you a special plea why New York, the largest city in this country, does not go on a meter basis. Nobody, presumably, in the water works business will ever claim that the meter basis of measurement of consumers' water is not the sound, desirable basis, without taking into consideration local conditions. But we probably will continue on the frontage basis for a good many years, and we probably will be criticized for failing to adopt modern methods.

The situation is that the people we serve do not want meters. The people we serve are perfectly willing to pay the additional sum, which is very small for the individual per annum, to continue the present system. And, after all, we are trying to please the people that employ us, to take care of their needs for a satisfactory water supply. If you are carrying on a general business on the City of San Francisco, and you knew that the people of San Francisco could save a certain sum, which would not be very large, but which would be a definite amount, and they would come to you if you did business in a certain way, you would not adopt a policy that would keep them away from your store.

It is questionable, in my mind, whether you should try to compel a large group of people to be dissatisfied for a number of years so as to save what I estimate to be approximately 50 cents a year per person, by forcing them to take their water supply in a manner of measurement that they do not want.

When you come to the political side of it, why should an administration that has the support of the people alienate a portion of that support by adopting a policy that would be offensive to that group, which is a substantial one? That is asking a man to commit political suicide, and he is not going to do it. He is not in it for his health;

he is in it for a business. It is a business of running a city by a political party. We ought to recognize that. I think that all of us make a mistake when we fail to take that into consideration in trying to carry on the city's business, which is the citizen's business, in what we think is a reasonable, efficient manner.

Mr. Fenkell has brought out very wisely something that some of us at times forget, and that is that the water supply business is one where it is to the advantage of the community, to the advantage of the entire country, to decrease the amount of the business; that is, the amount of the commodity sold. You can never get—this is a broad statement but practically true—you can never get a second supply as cheaply as you can get your first supply. And your third source of supply is still more expensive; because you go to the nearest one at hand that is satisfactory and develop that first. Then you go further afield for your second supply. The next time you go still further afield. That is true of the large as well as the small community.

Therefore, we as a group are doing our work most effectively if we can reduce the amount of water that is demanded, which is what we are selling, rather than increasing the sale of our product. That makes our business very, very different from the usual run of business.

THE ST. FRANCIS DAM FAILURE[1]

By A. J. Wiley[2]

The St. Francis dam was located on San Francisquito Creek, 9 miles above its confluence with Santa Clara River and 52.5 miles above the discharge of the Santa Clara into the sea near Ventura, California. The reservoir created by the dam had a capacity of 38,000 acre-feet, and was used for terminal storage for the surplus discharge of the Los Angeles Aqueduct.

The dam was of the solid concrete, gravity type, arched in plan. It had a maximum height of 207 feet above foundations, or 182 feet above stream bed. The radius of its upstream face was 500 feet and its length on top was 700 feet, beyond which was an extension in the form of a low wing wall along the crest of a ridge to the west of the main dam. Its thickness at the base was 168.85 feet at its maximum section, with a nearly vertical upstream face and a thickness at top of 16 feet. The spillway lip, which was the maximum elevation reached by the reservoir at the time of failure, was 3 feet below the top. The batter of the faces flattened more rapidly for heights in excess of 160 feet, above which, for an equivalent triangular section with vertical upstream face, the downstream face would have had a rise of 1.40 in 1, or a base of 0.71 of the height.

Such a section would have been perfectly safe for a concrete dam on rock foundation with the usual provisions against uplift, even if built on a straight line. Built as it was on an arch of 500 feet radius, it should have been safe, even with uplift drainage omitted, had it been firmly connected to a hard rock foundation.

The dam site was crossed by a fault parallel with the valley, the central part and east or left end being on mica schist and the right or west end being on red conglomerate.

The mica schist consists of thin layers of hard rock very weakly cemented together. The formation is so tilted that the layers are parallel to the steep slope on the east side of the valley. In fact,

[1] Presented before the San Francisco Convention, June 14, 1928.

[2] Consulting Engineer, Boise, Idaho.

the caving and sliding of the rock layers is responsible for the steepness of the east side of the valley at the dam site.

The fault line is nearly one-half of the height of the dam above the bottom of the valley. The strike is parallel with the valley and the dip is nearly parallel with the layers of the mica schist. On the lower side of the fault plane there is a gray gouge about 8 inches thick made of schist ground into clay. The schist under this gouge for a depth of about 10 feet is badly crushed and sheared by the faulting.

On the upper side of the fault plane there is a red gouge made of finely ground up red conglomerate which in places is 4 feet thick. Both types of gouge, though fairly hard when dry, become plastic and unctuous when wet.

The red conglomerate, which extends from the fault plane to the top of the dam on the west side of the valley, is a massive formation, except that it is intersected by many small seams which are filled with gypsum.

When dry the conglomerate is rather rock-like in appearance and character, but when placed in water it gives off bubbles of air and quickly begins to disintegrate into sand and clay. When perfectly dry, it has considerable strength, one sample crushing at about 2500 pounds per square inch, and another, cut from the eroded surface perhaps 20 feet below the original foundation, broke at 523 pounds per square inch.

The central part of the dam, about 80 feet long, which survived the failure, was founded on the mica schist about 25 feet below the stream bed in the lowest part of the valley. No cut-off trench was used in this section and no pressure grouting was attempted either here or in any other part of the foundation. Drainage wells were put under this section discharging through connecting pipes to a common outlet below the dam. No inspection or drainage gallery was used in this or any part of the dam, nor was drainage against uplift used elsewhere than in this central section.

Connection to the steeply sloping layers of mica schist at the east, or left end, of the dam was made by trenching into the rock for the whole width of the base and no cut-off trench at the upstream face was used.

Connection to the flatter slope at the west abutment was made by trenching into the formation and using a cut-off trench about 3 feet square in section near the upstream face.

The dam was completed in May, 1926, and storage was started two months before completion. The reservoir was filled to a depth of 125 feet by June 1, and held at that until September 1. It was then dropped 20 feet and held at that until January 1, 1927, when it was filled to a depth of 175 feet, or 5 feet below the spillway level, by April 20, and held there until the end of May, when it was dropped 15 feet, or to 20 feet below the spillway, and held there until November 15. It was then gradually filled until it reached the spillway lip, 3 feet below the crest, on March 5, 1928, where it was held until total instantaneous failure took place at midnight of March 12–13.

To trace the sequence of the failure, it may be stated that the mica-schist under the eastern and middle part of the dam has ample strength except for loads applied parallel to or at small angles from the plane of its layers. But when it is undercut the layers tend to slide easily one upon the other.

The central, or channel section, was founded upon this schist at a depth where it was fully supported. The 70 feet of the dam between the channel section and the fault was supported because the layers were dipping into and nearly normal to the slope. The foundation under the east wing had ample strength against any pressure from the dam because the dam itself was holding the layers in place.

The red conglomerate when dry had a compressive strength of 500 to 2500 pounds per square inch. The maximum pressure at the toe of the dam at the elevation of the lowest part of the conglomerate was not over 150 pounds per square inch and at the base where it was on the firmly supported schist, the pressure was not over 275 pounds per square inch.

The foundation when dry was strong enough to support the dam with reservoir either empty or full. With the reservoir empty there was maximum pressure at the upstream toe, but as the foundation was dry it had ample resistance. As the reservoir filled, the pressure at the upstream face was reduced at the same time that the resistance of the foundation at this point was being reduced by water softening. As the pressure on the downstream part of the base, due to reservoir filling, was increased there was a progressive softening of the foundation by the gradual seepage of the water toward the toe. Although the dam was designed to support the water pressure by gravity cantilever action alone, there was, from the first, a division of the load between gravity cantilever and horizontal arch action. As the resistance of the cantilever was decreased by the softening

of the foundation, more and more of the water load would have been taken by horizontal arch action had there not been the same weakening of the arch abutments as of the cantilever foundations. The foundations under the two-thirds of the dam on the mica schist were not materially reduced in compressive strength by water action.

The red conglomerate under the west third of the dam was, from its clayey nature, quite resistant to water penetration, but as the moisture slowly penetrated toward the downstream toe, the conglomerate was practically converted into a clayey sand. Under these conditions failure of the part of the dam located on the conglomerate was, of course, inevitable.

There are no living witnesses of the final catastrophe. It appears that there had been some seepage through the foundations which gradually increased with time and the increase of depth in the reservoir, but it was probably less than is usual in dams on hard rock foundations. In the day preceding the failure there seems to have been a marked increase in the foundation seepage, which was estimated at from 1 to 2 second feet, but there was no indication of weakness in the dam when it was inspected about thirteen hours before the failure. The water was being held just below the spillway lip with no water in the stream below the dam except that fed by the seepage.

The two watchmen and their families lived in a cottage almost immediately at the base of the dam and there was a village of about 50 people located on a little flat in a bend of the stream about a mile below. At a mile and a half below the dam was a 40,000 h.p. plant also directly upon the stream. About an hour before the failure one of the watchmen was seen upon the top of the dam.

The time of the failure is located at 11:58 p.m. March 12 by a break in a transmission line immediately below the dam, followed five minutes later by the shut-off of the power plant 1.5 miles below the dam. The record of a recording water level gage which remained on top of the still standing central section of the dam after the collapse of the east and west wings showed a gradually accelerating fall of the reservoir surface beginning thirty minutes before the failure and aggregating $\frac{3}{10}$ of a foot. This indicated a leak prior to the failure averaging 740 second feet for the first six minutes, 2200 second feet for the next eight minutes, and 15,000 at the end of the thirty minute period, with a very rapid acceleration to the final collapse five minutes later. This is, of course, upon the assumption

that there was no vertical movement prior to the failure in the part of the dam on which the gage was located. It seems reasonable to assume, however, that the gradual distortion of the dam due to yielding of the foundations, which must have preceded the failure, may account by upward movement of the gage for the apparent fall in reservoir surface.

It seems also that had there been, preceding the failure, a leak of the proportions indicated by the gage, it would have warned the watchmen, their families, the people of the village a mile below, and the operators in the power plant, all of whom were overwhelmed by the flood.

From all the evidence it appears that the initial failure was an instantaneous collapse of the greater part, and possibly the whole of the west wing which crushed and buckled as a horizontal arch, after failing as a vertical cantilever, under the eccentric loading due to the yielding of its water softened red conglomerate abutment.

The water thus released filled the narrow valley below to a depth of 125 feet. It had a velocity of 18 miles per hour, a volume of at least 500,000 second feet, and carried the west wing of the dam in blocks up to 10,000 tons, a half mile or more below the dam site.

The failure of the east wing appears to have followed immediately after that of the west wing, and to have resulted from the undercutting of the steeply sloping layers of the mica schist under the east wing by the tremendous eddy action of the torrent escaping from the collapsed west wing.

It appears probable that the east wing failed first at its extreme eastern end and was then undercut and dropped a section at a time by shearing along vertical radial planes located at contraction cracks, until nothing remained but the 80 feet long 200 feet high section at the center of the dam.

FAILURE OF THE ST. FRANCIS DAM[1]

By D. C. Henny[2]

The coroner's jury and five committees of engineers and geologists have officially investigated the cause of failure of the St. Francis dam. The technical press has rendered great service in reporting the event with remarkable completeness, in publishing impartially the various committees' reports and in adding very valuable comments of its own.

All reports as well as the press comments agree in the one outstanding conclusion that the failure was due to the foundation. There is, however, great diversity of opinion as to the principal delinquency of the foundation, and as to how it reacted upon the dam structure so as to produce initial failure. Moreover, some engineers of the highest standing attribute the disaster to the dam itself, its relatively weak concrete, its lack of water-tightness, the omission of contraction joints in first construction and the absence of a deep cut-off wall and of an efficient drainage system.

Those who lay the blame on the foundation differ as to whether it was the saturation of the conglomerate, or the penetration of reservoir water in the parallel seams of the schist, or an upward slip of the conglomerate along the contact plane which was mainly responsible. With such lack of unanimity, it is evident that definite assurance on the part of any one is not helpful and that the problem must be treated with an open mind, regardless of previously held opinions. The following discussion is offered in an effort to reduce to some extent the field of speculation and controversy.

The dam was built as a monolith of concrete which, when tested for crushing in 3-inch cubes gave a strength after three years of from 2200 to 1300 pounds. Such concrete cannot resist the tension which sets up on gradual dissipation of internal chemical heat, and numerous contraction cracks must have formed in the dam along planes of least resistance that is approaching the vertical and radial in the valley portion of the dam and inclined and radial in the abutments.

[1] Presented before the San Francisco Convention, June 14, 1928.

[2] Consulting Engineer, Portland, Oregon.

These cracks would extend quickly through the thin portion of the dam as at the top, but would only slowly reach the center of the thicker parts where cooling may take years even in spite of water penetration.

The dam as it stood the day before the failure must be visualized, therefore, as consisting of numerous blocks with some yet unseparated areas in the center. The dike on the west abutment, as might be expected, shows a number of cracks extending clear through. Evidence of cracks in the main dam is very meagre and no definite measurements could be obtained. It has been stated that among others a diagonal crack existed at an angle of about 45 degrees from the vertical in each of the abutment sections.

It seems probable that with rising water in the reservoir there was some expansion in the concrete due to saturation, but this in itself may not have produced closure except possibly near the base. It is, for instance, certain that cracks which had been calked must have been open after saturation, and there are two such cracks in the concrete dike and the diagonal crack in the east abutment is said to have been likewise calked. Neither would the cantilever deflection be sufficient to do more than partly close existing temperature cracks, at least in that part of the dam where toe loads on the foundation did not produce marked settlement.

It is evident that the remaining areas of adherence in the general planes of cracking must have been subject to large forces resulting from water loading, interior water pressure and temperature changes so far as they continued to extend toward the center of the mass concrete. These forces would tend to produce rupture by tension and by shear. Especially the crack which may have existed nearest the contact plane between conglomerate and schist may at an early stage have broken clear through due to uneven settlement.

Besides the main contraction cracks there probably existed many minor cracks, visible and invisible, extending along construction surfaces or other planes of local weakness due to shrinkage and shearing tendencies. The dam as a whole may therefore be conceived as consisting of a large number of irregular blocks, united only along limited areas of adherence.

The concrete was below the usual standard of strength, owing to the inferior character of the local aggregate used. The ordinary safeguards which have become common practice were omitted, such not only as radial vertical contraction joints but also deep cut-off and thorough drainage.

Such a structure stood on a foundation of schist and conglomerate as described elsewhere. With water rising against the dam, the conglomerate became slowly water soaked, seams in the schist were penetrated by water and water pressure was exerted in cracks in the concrete open on the water face and extending in directions varying more or less from the radial and vertical. Thus there were introduced various elements of serious danger.

The conglomerate foundation became softened by saturation and permitted a slow percolation which carried away portions of the gypsum which filled many seams of a width of $\frac{1}{8}$ to 1 inch, and in some localities 2 inches. This leaching caused additional water penetration, uplift and softening. This probably resulted in a yielding under toe load first where the dam resting on conglomerate is highest, and where toe compression due to a head of 93 feet of water must have been close to 9 tons per square foot in the direction of back slope. This yielding with continued softening must have gradually extended up the abutment slope until it permitted a slight tilting of a block, which must have been promptly followed by an increase of uplift at the heel and a serious decrease of foundation resistance to sliding.

Coincident with this process of weakening to the west the water entering schist cleavage planes to the east must have considerably reduced the sliding friction in that material. The general direction of the dip is fairly normal to the direction of the dam except near the top where the deviation is slightly less than 30 degrees. The east end of the dam was in a position to act with fair efficiency against sliding due to weight of masonry. Against motion in a downstream direction, however, the friction on schist layers may have become reduced close to the danger point. This was probably not accompanied by initial tipping and by serious increase of uplift as on the conglomerate end of the dam.

There was therefore imminent danger of sliding downstream at both ends of the dam. This would be opposed by arch action, but such action could be set up only to a very limited extent. The irregular cracking of the dam interfered to some extent with arch action. Also the angle at almost 30 degrees on the east side between horizontal arch thrust and line of strike in the schist which would cause a component along line of strike and might produce yielding by sliding. Principally, however, it is believed to be the softness of the west conglomerate which would have prevented any material arch resistance at least for the upper 90 feet of the dam.

The resistance to sliding downstream of the two wings of the dam was therefore gradually and simultaneously lessened until both were in a delicate state of equilibrium, and it is this fact which may be mainly responsible for the difference of opinion as to which end of the dam failed first.

It was argued above that the upper west or conglomerate end was probably in the most dangerous condition, and on that ground alone it might be logically concluded that the west end was the first to collapse. Another argument is that had rupture occurred on the east side first, the outflow from the reservoir would not have seriously affected the west abutment, where for the lower schist portion the dip is into the hillside and no slide could occur and where on the higher conglomerate slope no definite lines of cleavage exist.

Thus the relief afforded by a rapid lowering of the reservoir by outflow on the east would probably have allowed the west side wing to remain standing.

On the other hand, a rupture on the west side would almost instantaneously produce tremendous erosion at the base of the east abutment which, being in a previous state of delicate sliding balance, would in a few minutes produce extensive slides of schist causing undermining and rupture of the east wing.

It is on this basis of reasoning that the preponderance of opinion in favor of a first break on the west side is founded. It furnishes a logical explanation of the nearly simultaneous progressive collapse on both sides which ceased by the rapid emptying of the reservoir just in time to leave one block standing.

This block must for a moment have been on the extreme edge of collapse, as it appears to have tipped and possibly slid so that the top has moved about ½ foot in a radial and ½ foot in an easterly tangenital direction.

In regard to the theory, earnestly advanced in one engineering publication, attributing the failure to a general movement of the conglomerate upward along the inclined plane of contact, the principal fact upon which this theory is based is the rise of about 3½ inches of the west dike. This rise is however not uniform and since it diminished in the last 100 feet next the dam to less than one inch, this rise may be logically explained by a swelling of the conglomerate due to saturation. Such swelling has been observed elsewhere even to a greater extent where loads are light as, for instance, in the spillway steps of the Lahontan dam, in Nevada, which lie on somewhat

similar conglomerate. With higher loads such swelling would be completely prevented and would on the contrary be converted into settling, and it is doubtful therefore whether any rise existed in the dam proper a short distance from its west end.

Moreover, a general rise of conglomerate would have tended to shear the dam at some angle upward from the line where it crosses the plane of contact. It is probable, however, that even then its softness would have been unable to produce any great stresses in the dam other than those which were caused by permitting settlement and sliding.

As to the theory of the dam having been lifted from its base by swelling of the conglomerate at one end and upward pressure of a deep seated slide in the schist on the other end, the broken condition of the dam structure, and especially the diagonal cracks at the two ends, said to have existed as early as January, 1928, would have prevented such general mass uplift which in any event the saturated conglomerate would have been too soft to produce. Even had the dam been a monolith, tensile stresses along diagonal lines in the uplifted wings would have been introduced in overcoming weight and adhesion to a degree far beyond the strength of the concrete.

The final position of the standing block can hardly be an argument either way, as the jar in breaking through uncracked areas of masonry and in successive violent rubbing of each outgoing block against its still standing neighbor, is beyond means of calculation and almost beyond the field of speculation, as is also the relative position in which various chunks of masonry, in being swept down the valley by the flood, possibly passing one another in their course, were finally left upon the recession of the water.

The curious shearing of an outer skin of concrete containing many of the lower steps of the standing block and that adjoining to the east, has elicited considerable discussion. Planes of weakness in the original construction of the dam, together with expansion and contraction of the outer skin by temperature changes and intensified loads due to tipping under pressure of water, as also shocks during the brief period of collapse and the tumbling down of masses of masonry on the downstream slope may in part account for this. As a means of supporting any theory of collapse, this phenomenon appears to the writer of small value.

There remains to be considered the true meaning of the record traced by the Stevens recording gage on top of the remaining part of

the dam. The line shows a drop of 0.03 foot between 2 p.m. and 11:40 p.m., on March 12, then in the next half hour an accelerated drop of 0.22 foot and quickly thereafter a practically vertical drop.

This record was used in connection with reservoir areas to ascertain the apparent gradual increase of outflow which on that basis was bound to have reached a rate of 1000 second feet half an hour before collapse, then to have gradually increased to 25,000, followed quickly by a rate of over 500,000 second feet, which could only be due to rather general sliding out of blocks. The earlier rate of outflow however is not compatible with testimony to the effect that as short a time as thirty minutes, and possibly fifteen minutes, before the arrival of the big flood a short distance below the dam, passing automobilists found a dry road in the valley, which would have been flooded by a flow exceeding 10 second feet.

A suggestion has recently been made which seems logical to the writer. It is argued that the recorder merely traced the difference in level between its own position on top of the dam and the reservoir level. The curve drawn by the recorder may therefore be due in part or in whole to a rise in the dam. The downstream component of the movement at the top of the block is 0.5 foot. If this is all due to tipping about a line say 20 feet upstream from the lower toe, an upward movement would result of 0.30 foot. This would be reduced to the extent that top movement was due to sliding and that concentration of stresses at the toe may have produced additional compression of the schist foundation. The suggestion has the valuable feature of tending to reconcile credible testimony with the facts as found.

In so far as the writer has expressed opinions in a controversial field like the sequence and details of the failure, he intended to do so with due respect for the opinions of others and subject to revision of his own opinions if additional facts should warrant it. In the light of what is now known, he holds that the failure was due to incompetent foundation, that it was initiated by softness of the saturated conglomerate, and that first collapse occurred at the west end of the dam.

UNACCOUNTED FOR WATER[1]

By L. R. Howson[2]

The problem of reducing the quantity of "unaccounted for water" is like that of caring for the poor, "with us always." Well over one hundred years ago, one of our pioneer Eastern water works systems in attempting to reduce water waste passed a lengthy resolution, one paragraph of which required each consumer to report monthly the number of barrels of water used for bathing purposes and to pay therefor at 5 cents per barrel. If the consumer reported use, he must pay; if he failed to report, he was delinquent on bathing. So far as known, this is the only system of metering which consistently overregistered.

The term "unaccounted for water," as used in this discussion, is the difference between total water pumped for any given period and the summation of the meter readings of the individual consumers during the same period. All water works men recognize the fact that it is not practicable to distribute water without some loss, for minor losses are not easily detected and some of them are so small as not to warrant the expense required to locate and repair them. It is the purpose of this study and discussion to determine some of the factors having a bearing upon the amount of "unaccounted for water" and insofar as practicable to point out means by which this amount can be reduced.

It is recognized that the solution of any problem having so many variable factors cannot produce an exact mathematical result. If, however, some general conclusions can be deduced pointing toward means of reducing the "unaccounted for water" the time will have been well spent.

BASIS OF DISCUSSION

At the beginning of the study, a questionnaire was prepared, the questions of which were designed to bring out facts having a bearing

[1] Presented before the San Francisco Convention, June 12, 1928.

[2] Of Alvord, Burdick and Howson, Engineers, Chicago, Ill.

TABLE 1

Summarized data from questionnaire on "unaccounted for water"

CITY	TOTAL PUMPAGE, M.G.D.	TOTAL METER REGISTRATION, M.G.D.	PER CENT PASSING METERS	MAINS PER CENT CAST IRON	SERVICES PER CENT LEAD (OR COPPER)	JOINT MATERIALS PER CENT LEAD	DOES UTILITY OWN METER	DOES UTILITY DECIDE METER SIZE	IS PRESSURE RAISED FOR FIRES
1	4.424	3.674	83.1	97.0	86.8	90.0	Yes	Yes	Yes
2	18.820	14.666	77.8	99.6	100.0	100.0	Yes	Yes	No
3	28.577	18.575	65.0	92.5	0.0	100.0	No	Yes	Yes
4	1.167	0.679	57.3	59.4	33.0	75.0	Yes	Yes	No
5	3.100	1.676	54.1	47.1	0.0	94.0	87%	Yes	Yes
6	4.84	4.31	89.0	95.6	100.0	61.0	Yes	Yes	No
7	14.47	10.78	74.4	45.7	11.0	71.0	Yes	Yes	No
8	0.753	0.735	97.6	100.0	100.0	100.0	Yes	Yes	Yes
9	4.44	2.82	63.5	100.0	100.0	100.0	Yes	Yes	Yes
10	12.781	7.95	62.2	100.0	100.0	100.0	Yes	Yes	No
11	211.944	178.00	84.1	100.0	100.0	80.0	Yes	Yes	No
12	0.437	0.272	62.2	78.4	70.0	90.0	No	Yes	No
13	6.768	4.040	59.6	100.0	100.0	87.2	No	No	No
14	7.45	6.30	84.6	100.0*	100.0	100.0	Yes	Yes	Rarely
15	0.69	0.406	58.8	100.0	100.0	100.0	No	Yes	No
16	17.989	11.926	66.3	100.0	100.0	100.0	Up to 1"	No	No
17	5.191	3.800	73.2	96.3	100.0	100.0	20%	No	Yes
18	0.965	0.575	59.6	73.0	0.0	80.0	Yes	Yes	No
19†	4.48	3.20	71.4	100.0	100.0	100.0	Yes	Yes	No
20	8.017	5.45	68.0	80.5	0.0	76.0	⅝"	Yes	No
21	8.145	6.55	80.4	100.0	75.0	100.0	Yes	Yes	No
22	4.700	4.07	86.5	100.0	100.0	85.0	Yes	Yes	Yes
23	6.00	4.48	74.6	100.0	100.0	100.0	Yes	Yes	No
24	1.342	0.644	47.9	85.5	100.0	0.0	Yes	Yes	No
25	72.648	56.60	77.9	100.0	100.0	100.0	No	No	No
26	47.900	32.60	68.0	100.0	100.0	100.0	Yes	Yes	No
27	4.742	4.035	85.0	100.0	100.0	100.0	No	Yes	Yes
28	7.766	6.34	81.05	100.0	100.0	82.7	Yes	Yes	Yes
29	2.40	1.92	82.1	25.0	0.0	60.0‡	Yes	Yes	No
30	7.027	4.85	69.0	98.4	50.0	100.0	60%	Yes	No
31	29.937	20.10	67.2	100.0	100.0	100.0−	No	No	No
32	5.89	5.65	95.9	65.5	100.0	70.0	Yes	Yes	No
33	8.058	5.53	68.6	100.0	100.0	100.0	Yes	Yes	Yes
34	4.034	2.77	68.7	67.0	5.0	88.0	Yes	Yes	No
35	168.98	124.10	73.4	100.0	100.0	100.0	Yes	Yes	No
36	14.443	11.990	82.9	87.0	87.0	90.0±	No	Yes	No
37	2.104	1.630	77.4	100.0	0.0	100.0	Yes	Yes	Yes
38	2.230	1.590	71.3	30.6	0.0	40.0	No	No	No

* Steel, kalameined and wrapped-lead joints.

† Has 7000 hydraulic lifts.

‡ 40 per cent Universal.

TABLE 1—*Concluded*

CITY	TOTAL PUMPAGE, M.G.D.	TOTAL METER REGISTRATION, M.G.D.	PER CENT PASSING METERS	MAINS PER CENT CAST IRON	SERVICES PER CENT LEAD (OR COPPER)	JOINT MATERIALS PER CENT LEAD	DOES UTILITY OWN METER	DOES UTILITY DECIDE METER SIZE	IS PRESSURE RAISED FOR FIRES
39	11.005	6.616	60.1	96.8	100.0	100.0	Yes	No	No
40	3.489	2.680	76.8	97.5	82.5	98.8	Yes	Yes	No
41	9.00	7.94	88.2	100.0	100.0	85.0	Yes	Yes	No
42	4.216	3.782	89.9	51.5	0.0	5.0§	Yes	No	No
43	28.00	21.8	77.8	94.0	51.0	100.0	No	Yes	No
44	0.381	0.268	70.4	100.0	100.0	100.0	No	Yes	No

§ 95 per cent cement.

upon the item of "unaccounted for water" in individual water plants. It is, of course, obvious that the percentage of "unaccounted for water" in any plant is a composite result of the leakage from mains, services and under-registration of meters. However, it was felt that by comparing the data from a sufficient number of plants on the bases of the major items affecting the "unaccounted for water" some general conclusions might be drawn.

Questionnaires designed to elicit this information were sent out to 85 of the completely metered systems in the country, extending geographically throughout the entire United States and furthermore dealing with all kinds of water supplies and with as wide a variation of construction materials and operating conditions as it seemed possible to secure. From these 85 inquiries, the writer is indebted to the managers of 56 plants for replies with the information requested, and from these 56 complete replies, 44 plants were secured in which the measurement of the water leaving the stations was accurately determined and all the other data requested made available in such shape as to make it readily comparable with similar data from other plants. Table 1 shows a summarized tabulation of the principal data received in response to the questionnaire.

The 44 plants serve a total population of approximately 6,150,000 people. They pumped 801,726,000 gallons per day during the past year to 1,244,712 services, an average of 130.5 gallons per capita per day or 643 gallons per service per day. Of this amount, approximately 73.5 per cent of the water pumped passed through the consumers meters. The difference of 26.5 per cent represents the loss

between the station meters and the summation of all amounts registering on the consumers meters. This amount (referred to herein as "unaccounted for water") is so large, amounting to approximately 31 gallons per capita per day, that it is well worth serious consideration.

APPROXIMATE APPORTIONMENT OF UNACCOUNTED FOR WATER BETWEEN MAINS, SERVICES AND METERS

In order first of all to determine approximately the extent to which the "unaccounted for water" may be attributed to leakage in the mains, services and meters, respectively, a study was made of the records of pitometer surveys made in a large number of cities by the Cole Pitometer Company, who very courteously furnished the writer with the information thereon. An analysis of the leakage reported in 61 cities, for which leakage surveys have been made, showed that the average leakage from mains and services combined in the 61 towns was $16\frac{3}{4}$ per cent of all water pumped. In 14 of these cities in which the leakage data were separated out as between leakage from services and leakage from mains, it was found that approximately 56 per cent of the leakage from these two sources was attributable to mains and 44 per cent to services. These are equivalent to 9.2 per cent of the pumpage lost from the mains and 7.5 per cent lost from the services. A further analysis of 6 cities in which the leakage from large meters was also determined, showed, of the total leakage, approximately 30 per cent taking place from services, 26 from mains and hydrants and 44 per cent from large meters.

The Pitometer Company's figure of $16\frac{3}{4}$ per cent losses from mains and services only, in 61 plants, is 63 per cent of the average losses from all sources in the 44 plants considered herein. This compares with 56 per cent of the total losses in mains and services as found in the Pitometer Company's data for 6 plants only in which meter losses were included as a separate item.

It is believed that it is close enough for all practical purposes to assume that as a general average about 30 per cent of the total "unaccounted for water" may be chargeable to the mains and hydrants, 30 per cent to services and 40 per cent to the underregistration of meters. In individual plants, of course, these percentages will change. The writer has in mind one plant where it is believed at least 60 to 70 per cent of the "unaccounted for water"

is chargeable to the meters and another in which it is believed that the mains and services are properly chargeable with at least 75 per cent of the total water lost.

The losses from mains, services and meters obviously are each influenced by several factors, none of which can be isolated and determined accurately; however, by analyzing the entire number of plants as a group with respect to each of the variables, it was hoped some general inferences might be drawn and possibly some direct conclusions as to the effect of some variables upon the amount of "unaccounted for water."

LEAKAGE FROM MAINS

Some of the variables which may affect the amount of the leakage from mains are:

(a) The materials used in the construction of the pipe lines.

(b) The average pressures carried on the mains.

(c) Possibly the joint materials used.

(d) The character of the soil in which the excavation is largely made.

The questionnaire was accordingly so designed as to develop the facts relative to the mileage of cast iron, wrought iron, steel or other pipe materials in each system, the predominating type of soil, the materials used for making the joints, i.e., whether lead, leadite, metallium, hydrotite, etc., with the percentages of each, the average pressure on the system, whether or not pressure was raised for fires and whether or not the system had been surveyed in recent years for leakage.

It was expected that those cities having the largest percentage of cast iron pipe would probably show the largest percentage of water accounted for and the questionnaire proved that to be a fact. Of the 44 cities considered, 22 cities have nothing but cast iron pipe. These 22 cities accounted for an average of 74.9 per cent of all of the water pumped. The remaining 22 cities, having varying proportions of cast iron pipe, but with an average of 76.1 per cent of the system's mileage in cast iron, account for an average of 72.1 per cent of the water pumped. Accordingly, therefore, considering the effect of pipe materials only, the difference between 100 and 76 per cent of cast iron in the distribution system, would be indicated as approximately 4 per cent in the water accounted for.

The indicated effect of the pipe materials upon leakage is shown

somewhat more strikingly, if we compare the 7 cities which account for less than 60 per cent of the water pumped with the 7 cities that account for over 85 per cent of the water pumped. Whereas the 44 cities, averaging 88 per cent of cast iron mains, account for an average of 73.5 per cent of the water, the 7 cities which account for but 56.8 per cent of the water have only 80.2 per cent cast iron in their systems (i.e. 7.8 per cent less cast iron than the average and 16.7 per cent greater water unaccounted for) and the 7 cities which account for an average of 89.5 per cent of all water pumped, have 94.4 per cent of their systems in cast iron—(i.e. 6.4 per cent more cast iron than the average and 16 per cent more water accounted for).

Cast iron as used herein includes steel pipe kalameined and coated and laid with lead joints.

Obviously, higher pressures mean greater leakage through given openings in mains. Other conditions being equal, doubling the pressure will increase the leakage approximately 40 per cent. It is interesting in this connection to note that one of the cities having the greatest percentage of unaccounted for water, is required to maintain an average pressure throughout the system of between 95 and 100 pounds, in order to supply a number of hilltops. The unaccounted for water in this city (42.7 per cent) is comparable to approximately 30 per cent in the average city.

The data relative to joint materials is such that no conclusions can well be drawn from it. In 26 cities which use lead joints exclusively, 73 per cent of the total water pumped is accounted for, whereas in the remaining 18 cities which have used substitutes for lead to some extent and which average 19½ per cent of the mileage with lead substitutes, 74.6 per cent of the total water pumped is accounted for. However, when the seven cities having less than 60 per cent of the pumpage accounted for are compared with 7 cities accounting for more than 85 per cent, the following facts are developed: In the seven cities which account for an average of but 56.8 per cent of the water pumped, 37.7 per cent of the joints in the system are made with a lead substitute, whereas in the 7 cities which average 89.5 per cent of the pumpage accounted for, but 14.1 per cent of the joints are laid with lead substitutes.

LEAKAGE FROM SERVICES

The leakage from services is believed to be most largely dependent upon the type of material used for construction, that is, whether

wrought iron, lead, copper, etc., although an effort was made to develop through the questionnaire such facts as might assist in determining whether the conditions under which the service was laid and by whom the service was laid might have some bearing on the matter. As a result of the questionnaire, it was found that 26 of the cities used lead (or copper) services exclusively and that the average of these cities account for 74.3 per cent of all water pumped. Whereas the 18 cities which use other than lead services, largely wrought iron, and which have an average of but 30.6 per cent lead services, account for but 72.2 per cent of the pumpage.

The indicated effect of service materials on unaccounted for water is somewhat more marked if we again study the figures in those cities which showed the lowest and the highest percentages of unaccounted for water respectively. This comparison shows that while in the 44 cities which average 73½ per cent of water accounted for, 71.6 per cent of all services are of lead, the seven cities which account for but 56.8 per cent of water pumped, have but 62 per cent lead services, (i.e. with 9.6 per cent less lead services than the average, 16.7 per cent less water is accounted for). The seven plants having the best record for accounted for water and which account for 89½ per cent, have 100 per cent lead services—(i.e. with 28.4 per cent more lead services than the average, they account for 16 per cent more water).

In considering the effect of service materials, it should be remembered that, in most cases, lead services extend only from the main to either the curb or property line and where inside meter settings are used, a large amount of wrought iron or steel is in the service line ahead of the meter in any event.

UNDER-REGISTRATION OF METERS

As nearly as can be judged from the general data, the greatest proportion of all unaccounted for water from any single cause is probably due to the under-registration of meters. It is a common water works experience that small meters as at present developed, largely under-register due to their inability to measure the very small flows such as result from many types of fixture leaks and the large meters fail to register the water passing them at rates of flow which are small in proportion to the capacity of the meters but large nevertheless. There are, however, other factors which affect the amount of the losses through meters, some of which are brought out clearly by the questionnaire.

Some interesting replies were received to that question which asked whether the water utility or the consumer decides as to the size of meter to install on the consumers premises. One plant manager replied that "Consumers decide the size of all services and meters. It is immaterial to us as long as they pay the bills." That utility has 23 per cent of its meters larger than $\frac{5}{8}$-inch as compared to 5.4 per cent in the average of the 44 plants and accounts for but 60 per cent of the water pumped.

Figures developed from the questionnaire show that, in the 33 plants where the utility decides the meter size, 75.1 per cent of the water pumped is accounted for, whereas in the remaining plants where the consumer decides the meter size, only 70.7 per cent of the water pumped is accounted for. In other words, these figures would indicate that there is something over 6 per cent advantage in the utility rather than the consumer determining the size of meters. The reason for this is obvious. Consumers want large meters, if they cost them no more than small ones. Large meters register small flows and all ordinary fixture leakages much less accurately than do small meters.

The figures were also analyzed to determine whether there was any advantage, which could be expressed definitely in the terms of water unaccounted for, in the utility owning the meter. It was found that, in 30 cities where the utility installed and owned the meter, 74.8 per cent of all water pumped was accounted for, whereas in 14 plants where the consumer owns the meter, only 70.6 per cent was accounted for. In other words, where the utility owns the meter, it receives payment for about 6 per cent more water than where the consumer owns the meter.

Comparing again the 7 cities accounting for the smallest percentage of water pumped with 7 accounting for the largest percentage, it is found that only 3 of the 7 cities with the smallest percentage own all of their meters, whereas 6 out of 7 of the plants having the best record own all of their meters.

REGISTRATION OF METERS ON SMALL FLOWS

In an effort to determine the average ability of household meters to register small flows, request was made upon a number of plant managers through the middle west that they take a number of $\frac{5}{8}$-inch meters out of regular service, meters which had not in any way indicated the need for repairs, and that these meters be tested on

flows varying from 100 to 500 gallons per day. About 300 meters from 8 different plants were tested in this way.

In one plant, it was found that not a single one of twelve $\frac{5}{8}$-inch meters, (which represented four different manufacturers and ages varying from 2 to 22 years) would register at 100 gallons per day and that 10 out of 16 other meters, representing seven different manufacturers, and with ages varying from 2 to 30 years, failed to register at all at a rate of 500 gallons per day. The average accuracy of registration of the 16 meters at 500 gallons per day was but 21.6 per cent. The maximum percentage accuracy of any of the 16 meters at 500 gallons per day was 65 per cent. That plant is furnishing an underground supply and has had some occasional sand troubles from time to time extending over a period of several years. The distribution system is well built and efficiently maintained. There is every reason to believe that the loss from mains and services is less than the average and that the condition of the meters is responsible for a large percentage of unaccounted for water.

Another plant pumping unfiltered lake water reported 10 per cent of its meters failing to register at all under a flow of 100 gallons per day and 90 per cent registering at various rates from 43 to 100 per cent with an average for all meters of 39.3 per cent accuracy of registration at 100 gallons per day. At 360 gallons per day, the weighted average accuracy was 89 and at 720 gallons per day 95.7 per cent. These meters have an average efficiency of registration approximately meeting the standard requirements for new meters. In this plant, all $\frac{5}{8}$-inch meters are tested at least once in five years.

A third plant using a filtered river water, reported 20 per cent of its meters failing to register at 100 gallons per day, but the other 80 per cent registered from 97 to 100 per cent accuracy. These meters had been in service from one to eighteen years since last tested. This plant manager advises that their meters become "slimed" to which fact he attributes part of their high accuracy.

Taken as an average of all of the meters tested, it was found that 24 per cent failed to register at all at 100 gallons per day and that the average accuracy of registration of all the meters tested at 100 gallons per day was approximately 50 per cent.

Eighteen per cent failed to register at $\frac{1}{4}$ g.p.m. (360 g.p.d.) and the average accuracy at this flow was 67 per cent. Approximately 50 per cent of the meters in service passed the 90 per cent accuracy requirement of the standard specification.

TABLE 2

Summarized data on tests of ⅝ inch meters at small flows

City	Meters tested at 100 G.P.D.		Meters tested at 360 G.P.D.		Remarks
	Number of meters	Per cent accuracy	Number of meters	Per cent accuracy	
A*	12	0			Seven makes of meters from 2 to 30 years old—no set rule for frequency of testing. Plant has had some sand troubles. Underground supply.
			10	0	
			1	10	
			1	20	
			2	62	
			2	65	
	Average	0		21.6	
B	1	0			Deep well water—2 makes of meters averaged 92.3 and 67.4 per cent respectively. Test every 4th year.
	2	55–60			
	5	85–90			
	6	90–96.5			
	Average	79.9			
C	10	0	2	0	Unfiltered lake water—careful maintenance given meters. Test at least every 5th year.
	33	0–50	2	0–50	
	38	50–75	11	50–75	
	19	75–100	62	75–98	
	Average	39.3	23	O. K.	
			Average	89.3	
D	2	0	1	0	Four makes—service varied from 1 to 18 years since last tested. Filtered river water—Meters "Slime" test at 50,000 c.f. or 10 years time.
	1	97	3	90–98	
	7	98–100	6	98–100	
	Average	80		87.5	
E	5	0	(3 makes)		Filtered lake water. Now test at registration.
	2	65–75	(2 makes)		
	1	85–90			
	12	Over 90	(3 makes)		
	Average	67.8			
F	1	9			Two makes of meters from 1 to 27 years old. Filtered river water. Test at least every 7 years.
	1	24.7			
	6	73–79			
	Average	60.2			

TABLE 2—*Concluded*

CITY	METERS TESTED AT 100 G.P.D.		METERS TESTED AT 360 G.P.D.		REMARKS
	Number of meters	Per cent accuracy	Number of meters	Per cent accuracy	
G	1	0	2	30–40	Filtered river water. No general rule for testing. 6 makes included in tests.
	2	0–50	4	40–80	
	5	50–75	2	80–90	
	11	75–100	9	90–100	
	Average	81.5		81.8	
		(a)		(b)	
H	22	0	8	0	Meters in service from 17 to 27 years. Filtered water. Frequency of test determined by registration.
	2	20	1	30	
	6	40	4	40	
	6	60	2	50	
	1	80	6	60	
	1	100	2	70	
	Average	21.6	7	80	
			4	90	
			4	100	
			Average	55½	

Straight average of 8 plants—53.8 per cent accuracy at 100 g.p.d.
67 per cent accuracy at 360 g.p.d. ±

Approximate average of all plants—24 per cent failed to register at all at 100 g.p.d. and 18 per cent failed to register at all at 360 g.p.d. +

* Plant A meters tested at 100 and 500 g.p.d. (a) Tested at 180 g.p.d. (b) Tested at 720 g.p.d.

In *A*— 0 meters out of 16 passed standard requirements.
C—65 meters out of 100 passed standard requirements.
D— 9 meters out of 10 passed standard requirements.
G— 9 meters out of 17 passed standard requirements.
H— 8 meters out of 46 passed standard requirements.
Totals 91 meters out of 189 passed standard requirements.

Table 2 shows a wide range in results in the different plants.

In general, the figures secured would indicate that meters used on filtered waters will measure small flows somewhat more accurately than those measuring ground waters or unfiltered surface waters. This is probably due to the removal of all suspended matter by the filters and the possible "sliming" of the meters with the coagulant of the filtered water.

A number of 1 inch meters were also tested, which indicated weighted average accuracy of about 44 per cent on a flow of 360 gallons per day and approximately 73 per cent for 1080 gallons per day. Approximately 50 per cent of the meters registered over 90 per cent accuracy at the rate of $\frac{3}{4}$ g.p.m.) the minimum test requirement of the standard specifications.

Nearly 60 per cent failed to register at all at a flow of 360 g.p.d. and 30 per cent failed to register at 1080 g.p.d.

The above figures show conclusively that household meters in ordinary service do not register the small fixture leaks and this fact is believed to account for the low percentage of accounted for water in many cities. One of the cities that has had difficulty to control its amount of "unaccounted for water" reports that it has 7000 hydraulic pumps in service. These pumps are actuated by city pressure so that whenever water is drawn from a fixture in the house it pumps water from a cistern to a tank usually located in the attic. All of these pumps leak around the packing and experience has shown that practically all of the meters in service failed to register the leakage from this source.

The writer lives in a "hard water" city where hundreds of these hydraulic pumps are in use and has inspected a great many, all of which leaked continuously an amount fully as great and in many cases much greater than the amount shown on the water bill which should of course reflect both use and waste.

The two following illustrations show practical means of "legitimately" stealing water.

In one of our larger cities, it was observed that the Chinese laundries used surprisingly small quantities of water. Inspection showed the reason. The Chinamen had discovered that their meters did not click on small flows and had equipped tubs for storage, into which the water dripped continuously and from which it was taken as needed. All the water passed through the meters, but little of it registered.

It was reported to the writer recently that an enterprising refrigeration salesman was advising prospective customers that the installation of his equipment would slightly increase the gas bill, but would not affect the water bill as the cooling water was needed only in such small amount that the meter would not measure it.

Not all of the under-registration of meters, however, can be charged to the small meters on the premises of the ordinary domestic con-

TABLE 3

Summarized data on tests of 1-inch meters at small flows

CITY	METERS TESTED AT 100 G.P.D.		METERS TESTED AT 360 G.P.D.		METERS TESTED AT 1080 G.P.D.	
	Number	Per cent accuracy	Number	Per cent accuracy	Number	Per cent accuracy
A	1	60	4	0	2	0
	8	0	2	75–85	1	80–90
			3	93–97	6	97–100
	Average	7		50		75.6
C			1	0	1	0
			1	4	1	92
			2	30–50	2	96
			2	60	1	98
			4	75–90	4	100
			Average	53		87
E	9	0	5	0	2	0
	1	60	1	77	1	89
	Average	7	1	83	2	97
			1	93	2	99
			1	95	2	100
			1	97		
			Average	50		78
H			17	0	8	0
					1	20
					1	40
					2	50
					1	60
					1	70
					2	80
			Average	0		28

Average accuracy at 100 g.p.d. = 7 per cent.
360 g.p.d. = 38 per cent.
1080 g.p.d. = 67 per cent.

In *A*— 7 out of 9 meters passed standard requirements.
***C*— 8 out of 9 meters passed standard requirements.**
***E*— 6 out of 9 meters passed standard requirements.**
***H*— 0 out of 17 meters passed standard requirements.**
Totals 21 out of 44 meters passed standard requirements.

sumer. It is a well known fact that the ordinary dwellings use but little water and that a comparatively small proportion of the consumers in the average water works plant use a relatively large percentage of the total water pumped. In the average plant over 50 per cent of all consumers use less than 100 g.p.d. and the aggregate amount of their use is less than 10 per cent of the pumpage. Table 4, compiled from the statistics of plants appraised in the writer's office, is of interest in this connection. It shows that as an average approximately one-half of 1 per cent of the consumers will use approximately 30 per cent of the pumpage, which is equivalent to approximately 40 per cent of the total water sold.

TABLE 4

Water used by large consumers

CITY	CONSUMERS		USE G.P.D.	PER CENT TOTAL PUMPAGE
	Number	Per cent of total		
A	17	$\frac{1}{4}$	755,000	28.0
B	25	$\frac{1}{5}$	1,180,000	29.0
C	274	$1\frac{1}{4}$	2,050,000	25.0
D	30	$\frac{6}{10}$	900,000	14.4
E	15	$\frac{1}{4}$	1,500,000	31.0
F	25	$\frac{6}{10}$	385,000	20.0
G	20	$\frac{1}{3}$	1,040,000	37.0
H	25	$\frac{6}{10}$	2,340,000	51.0
Averages		0.5		29.4

The average daily use of each of these consumers comprising one-half of 1 per cent of the total number of consumers is approximately 50,000 g.p.d.

Analysis was also made of the meter sizes in a number of representative plants. The facts relative to the number of meters over 1-inch in size in 10 plants is shown in table 5. From this table, it will be noted that, out of a total of approximately 110,000 services, there are only 1130 meters over 1-inch in size, or approximately 1 per cent. Of this number, only $\frac{1}{5}$ of 1 per cent were larger than 2-inch.

In the average plant, approximately 95 per cent of all meters are $\frac{5}{8}$-inch, 4 per cent are $\frac{3}{4}$ and 1-inch, $\frac{4}{5}$ of 1 per cent are $1\frac{1}{2}$ and 2-inch and $\frac{1}{5}$ of 1 per cent are over 2 inches. These figures are of interest in

studying the allocation of the total meter under-registration to various sizes of meters. If in a typical plant containing 10,000 meters and using 5 million gallons of water per day, the meters were to register at 90 per cent accuracy for each of the sizes as outlined in the standard specifications for water meters and all services be running at these test rates, the $\frac{5}{8}$-inch meters would account for approximately 81 per cent of the under-registration. Meters over 2-inch would then account for approximately 5 per cent of the total water lost chargeable to meters.

In actual practice, as determined from the tests of the meters in the 8 plants selected as typical, only 50 per cent of the meters in service, however, meet the minimum flow requirements of the standard specifications and the actual accuracy of $\frac{5}{8}$ and 1-inch meters instead of being 90 per cent, is 67 per cent at the minimum test flow, which would increase the loss if all services were carrying the minimum test amount from 10 to 33 per cent. Only the education of the consumer to eliminate visible leakage on his premises has made it possible to account for so large a percentage of water as is even now done. The meters themselves would not accomplish the result. This indicates the advisability of the inspection of plumbing fixtures on the consumers premises even on 100 per cent metered systems.

Inspection alone, if consistently and efficiently done, can greatly reduce pumpage, as is so well demonstrated by a few plants. Its failures are, however, so numerous as to make it only commendable as an auxiliary of metering.

Large meters are frequently found to be passing considerable quantities of water without registration. The large meters usually installed on such lines, as those supplying railroad water tanks or water cranes, are designed to pass large quantities of water with low friction losses. If there are also attached to these high rate of draft lines, such other smaller uses as office buildings, shops, lavatories, etc., it is quite frequently found that the uses other than those of the large use, for which the capacity of the meter was designed, are not accurately registered, if at all. The adoption of compound meters does not always solve the difficulty.

An illustration of the slip through large meters was had recently when a railroad, which had been purchasing water from a utility through two 6-inch meters, discontinued service. The two 6-inch meters were disconnected and much to the surprise of the utility,

the pumpage dropped over 400,000 gallons per day more than the railroad had been paying for, indicating a loss through the slippage through these two meters of that amount.

METER TESTING

Much difference of opinion has been expressed to the writer as to a routine for testing meters. Mr. George G. Earl, past president of the American Water Works Association, advises that a short time ago, he removed 2000 meters for testing. He found that only 40 per cent warranted removal and that 60 per cent removed "on suspicion" did not warrant the expense. The meters tested varied in age from five to seventeen years. The oldest meters showed as high a percentage of accuracy as the new meters. Practically none of them would register at all at 100 gallons per day, but 50 per cent were over 90 per cent accurate at $\frac{1}{4}$ g.p.m. (360 g.p.d.) and 98 per cent accurate at 1 g.p.m.

Mr. Bohmann of Milwaukee has also come to the conclusion that it does not pay to test meters based on years service.

Other are reducing the maximum length of interval between periodic tests in some cases to as low as once a year. The practice in most plants is apparently to test at stated registrations or at least once in about four years for $\frac{5}{8}$-inch, once in two years for $\frac{3}{4}$ and 1-inch and at least annually for all over 1-inch in size. It would seem that the best interval can best be determined individually for each plant from a study of its own operating experiences.

It is the writer's opinion, and this is borne out by the test data on various plants studied herein, that meters must be periodically tested, the time to depend on registration with a maximum time limit for meters on light service. It is believed that those who do not approve of routine testing, disagree rather with the present facilities for making those tests and consider the present costs of testing to outweigh the benefits resulting therefrom.

If the removal of meters from service on suspicion or at stated frequent intervals is not warranted due to the expense incident to the removal and testing, it would seem desirable that there be developed some form of test meter which can be inserted in series with the meter as installed and which will furnish an accurate, quick check of any flow, no matter how small, which may not now be registered by the service meter.

FREE WATER AS AFFECTING UNACCOUNTED FOR WATER

Of the 44 cities, 9 advised that all public uses other than fires and flushing streets and sewers, are metered, but no charge made therefore. An average of 7.45 gallons of water per capita per day are thus served to 3,423,000 people for which no charge is made.

Nineteen cities in which the public uses are both metered and charged for, usually at the same rates charged to other consumers, use an average of 6.83 gallons per capita per day. A comparison of these two figures shows little difference. It had been thought that those cities which metered, but did not charge for the public uses, would show a substantial excess over those which both metered and charged.

Considerable data are available showing the effect upon the water furnished by private utilities as "free water" before and after a charge is made. In the early franchises, most of our midwest cities granted "free water" to the municipalities. Within recent years, the state utility commissions have been abolishing this practice and it has been almost the universal experience that where "free water" is abolished, the quantity of water used by the municipality has been cut at least in half. The writer recalls one incident in which a city was operating approximately 100 flush tanks for sewer flushing. The water used by these was supposed to be controlled by orifices of such opening as to fill and discharge a 500 gallon tank once a day. The water company had for years, pleaded with the city to so maintain these orifices as to keep the use somewhere near 500 gallons per flush tank per day, but without avail. A new rate schedule was put into effect by which the utility charged the city regular meter rates for the water used by these flush tanks. The immediate result was the repair of the flush tanks, followed within a few months by the abandonment of the greater part of them.

FREE WATER UNMETERED

The water used for fires is unmetered. However, many plant managers estimate its amount by keeping a record of the duration of fires and the number of streams used. Twelve plants so operating furnished their estimates for the past year. Reduced to percentage of pumpage, they varied from 0.08 to 0.24 of 1 per cent with an average of 0.15 per cent.

Street flushing, sewer flushing, etc., brought the total in three cities

reporting in this way to 0.91, 0.87 and 6.6 per cent respectively, the last named city including water used in rather an extensive street paving program.

TABLE 5

Proportion of large meters in use

CITY	TOTAL NUMBER OF SERVICES	NUMBER OF METERS OVER 1 INCH						TOTAL OVER 1 INCH
		1½ inches	2 inches	3 inches	4 inches	6 inches	8 inches	
1	7,228	9	28	4	3	1		45
2	12,999	39	48	13	10	1		111
3	8,350	9	82	38	23		1	153
4	9,286	42	73	11				126
5	4,186	10	10	3		1	1	25
6	7,000	39	119	4	4	5		171
7	20,389	73	147	12	15	7		254
8	3,147	17	15	1	2	1		36
9	19,000	44	20	5	14	12		95
10	18,271	48	44	10	8	2	2	114
Totals...	109,856	330	586	101	79	30	4	1,130

TABLE 6

Public use of water in cities; metered but not charged for

PLACE	POPULATION	PUBLIC USE
		gallons per day
Akron	208,435	360,000
Chattanooga	95,000	620,000
Des Moines	141,441	290,000
Detroit	1,242,044	9,950,000
Fall River, Mass	129,662	865,000
Lexington	46,895	75,500
New Orleans	414,493	3,290,000
Cleveland	936,485	8,800,000
Columbus, Ohio	237,031	1,260,000
Totals	3,441,486	25,510,500

This is equivalent to 7.45 g.p.d. per capita.

CONCLUSIONS

A study and analysis of the statistics from the 44 cities indicates the following conclusions as warranted:

1. Cast iron or steel pipe with other than screwed joints is best from the leakage standpoint.

2. Lead and copper services are better materials, from the leakage standpoint, for the laying of service pipes than is wrought iron.

3. It is to the utility's interest to own the meters. The advantage, expressed in unaccounted for water, of the utility rather than the consumer owning the meter, is approximately 3.8 per cent of all water pumped, or 6 per cent of the water sold.

TABLE 7

Public use of water in cities; both metered and charged for

PLACE	POPULATION	PUBLIC USE
		gallons per day
Bluefield	17,529	61,041
Charleston	73,125	364,000
Davenport	52,469	191,000
Fairhaven	10,827	104,000
Gary	76,870	485,000
Grand Rapids	153,698	503,000
Kenosha	50,891	242,000
Knoxville	95,464	214,000
Lansing	70,752	252,000
Milwaukee	509,192	6,430,000
Oak Park	51,420	124,000
Oklahoma City	91,295	288,000
Orlando	22,255	68,500
Racine	67,707	324,000
Springfield, Ill	63,923	191,000
Terre Haute	71,071	362,000
Waterloo	36,771	99,000
Richmond, Ind	26,765	141,000
Stockton, Calif	48,500	425,000
Totals	1,590,524	10,869,541

This is equivalent to 6.83 g.p.d. per capita.

4. The utility rather than the consumer should decide as to the size of meter to install. This decision is worth to the utility approximately 4.4 per cent of the water pumped or 6¼ per cent of the water sold.

5. There is some advantage from the standpoint of unaccounted for water in charging for, as well as metering, all public water uses.

SUGGESTIONS

It is believed that the following suggestions, if adopted, may assist toward the reduction of the amount of "unaccounted for water."

1. All services should be of lead (or copper) and these materials should extend from the mains to the meters rather than to the property line only, in the case of inside meter settings.

2. There is need of an accurate means of testing water meters at small flows without removal from service. The standard tests of water meters which do not go below about 360 gallons per day (three times the average use of the ordinary consumer if used at a uniform rate throughout the day) is too high.

Meters should not only be able to register small flows more accurately, but there is need for a portable device which will permit of checking the ability of meters to measure small flows with small expenditures for testing.

3. The utility should own all meters and maintain them according to its own standards.

4. The size of meters installed should be as small as practicable for the service. Larger pipe and smaller meters should be the aim.

5. The adoption of a graduated "service charge" based on the area of the meter opening will assist in the proper selection of meter sizes. Large "minimum charges" are not so effective for small users as some of them become wilful wasters so long as the minimum is not exceeded.

6. The use of hydraulic pumps and water actuated devices requiring packing and maintenance by the consumer in order to eliminate small leaks which will not be recorded on the ordinary service meter, should be discouraged if not absolutely prohibited.

7. The use of screwed joint pipe in the distribution system should be limited to lines laid in advance of development with the idea of replacement with cast iron as soon as the business warrants.

8. Every water department should have facilities for accurate measurement of all pumpage as well as all water sold. A comparison of the two figures should be made at least annually. Any unusual variation should be promptly analyzed.

ACKNOWLEDGMENT

The writer desires to express his indebtedness to the large number of water works men who have given freely of their time, data and

suggestions toward the preparation of this paper. He is particularly indebted to those who have made a large number of individual meter tests to determine the accuracy of registration at small flows. In view of the confidential nature of some of the test data furnished and the desire of some of the contributors that it be so kept, it has been decided to dispense with all personal references.

DISCUSSION

A. U. Sanderson:[3] I have listened to Mr. Howson's paper with a great deal of pleasure. There appear to be two schools of thought with regard to meter requirements. One school wants extreme accuracy and a meter which will never over-register. The other will accept the general standard provided by the manufacturers and is satisfied with that.

The manufacturers state that they can supply the extremely accurate meter, but they make some reservations, which are that the meter will not last as long and that it will become inaccurate much sooner. I would like to ask Mr. Howson which type he would prefer.

There is also another point I want to mention, and that is in connection with the water used for fire purposes. Do I understand that it is the practice in the United States to meter all the water consumed in fire fighting? Because, if so, I do not think it should be a charge upon the consumer who actually uses that water. In most cases there is a charge for hydrant rental, or the equivalent of a hydrant rental, which is a general charge on the taxpayer. That, as a rule, is paid out of the general tax rate. The consumer should not pay twice.

F. J. Sharkey:[4] I should like to ask Mr. Howson concerning the fact that the utility ownership of the meter instead of the consumer's influences the rate of registration. Is he serious in regard to that?

L. R. Howson:[2] Answering Mr. Sanderson's question as to the metering of water used, first. As far as I am able to find out only a very small percentage of United States cities make any record at all of the amount of water so used. Out of all the eighty-five ques-

[3] Superintendent, Filtration Plant, Toronto, Can.
[4] Wenatchee, Wash.

tionnaires to which I received replies, only twelve estimated it by a method which to me seemed accurate. The others were simply a blanket estimate.

But in these twelve plants the fire chief, or someone delegated to do it, kept a record of the number of fire streams, the number of minutes they were on, and from that they computed the flow. That is only in twelve cities out of eighty-five of the completely metered cities which are more likely to do it, by and large, than those which are not completely metered.

As to my opinion regarding extreme refinement or more durability in meters, I would be satisfied with the existing meters, if we had some method by which they could be checked up cheaply and accurately for small flows. It seems to me that at the present time, due to the necessity of spending from $2 to $5 to take out even a small meter and have it tested at the shop, most of us come to the conclusion that removing meters on suspicion is not warranted. That is probably true.

If that is true, then until we get some better method of testing them, I personally would be in favor of a meter capable of greater refinement in registration. But it seems to me that the real development should go toward some method of putting some type of a sensitive meter in series, simply through two pipe openings left for that purpose; in series with the meter as it *is* in operation and testing it for some small volume, a quart or a gallon, for actual displacement. This way you can test it without opening the fixtures. This would be a test to determine its ability to measure the small leaks of 100, 200 or 300 gallons which we know are now going through our large meters continuously.

I lived for many years in a city that used hydraulic pumps. Being interested in water waste, I tried to keep the hydraulic pump packed. When it was packed too tight the pump went slowly; friction cut the pressure down. I actually found that my meter did not register, at least, it scarcely registered at all. I had a minimum water bill for months. The minimum was leaking past my pump and was visibly much more than that.

I took that pump and had it tested and replaced. My water bill tripled. The waste was eliminated. I was using less water, but was using it at high velocities when the faucet was open.

Answering Mr. Sharkey's question about consumer-owned meters, I think the principal objection in the towns in which I have been in

contact with that particular practice, is that when the consumer puts in the meter, the man who owns it has no anxiety to see its registration maintained at 100 per cent or anything like it. When the meter is thought to be registering too slowly, the utility wants to test it, bills the consumer for it, and receives a roar about it when the bill is presented.

I think that the ownership of meters by the utility eliminates that. Over a period of years, in dollars and cents, it amounts to the same thing to the consumer. He either has to pay for it bodily or in interest and depreciation to the utility.

A. P. Michaels:[5] We cut in right ahead of the meter for testing. We have a flexible hose connection and we do not remove the meter but just cut ahead of the meter and check it on the ground.

This method is used where any meter is under suspicion. In the case of a complaint of a high bill or any adjustment, the operating men are sent right out on the location. The first thing is to establish the accuracy of the meter before any attempt is made to adjust the complaint, or to justify the complaint with the customer. We establish the accuracy of the meter on the ground without bringing it in.

Wm. W. Brush:[6] I personally expect to spend a lot of time studying this very excellent paper presented to us by Mr. Howson. I think we are all greatly indebted for so splendid a presentation. It gives us a very fine picture of the meter situation.

In New York I know we have a number of situations that are not to our liking. It takes us a long time and we have to pay for repairs when we do not own the meter. The people object to taking out the meter because of the expense involved. It amounts to a large sum. The plumber never cuts his bill down to anything like the price the owner thinks is reasonable.

I was surprised to learn just before I left for this meeting that we would lose about 15 per cent of our meters' revenue if we started to test. We sent out engineers to see to what extent it would pay us to test meters regularly, and that was what their investigation indicated. We have about 25 per cent of our services metered and we register about 27 per cent water supply through the meters.

[5] General Manager, Utilities Commission, Orlando, Fla.

[6] Vice President, American Water Works Association; Chief Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

D. C. Grobbel:[7] We in Detroit have the policy of having the department own all the meters. We control and set the meters. If there were individual ownership, the owner of the meter would not be as careful of the property as he is when there is a penalty attached for negligence.

We believe that is one of the most important phases in determining the size. In fact, I want to call your attention to a little matter that occurred about several years ago to one of the officers of the department who lived in a fourteen-family apartment building. The department was having a pitometer survey made. Unbeknown to any one they picked out a certain section and made a survey and checked up on the apartment house in question. They discovered that this apartment house had a 4-inch meter that registered only four gallons night flow—in a fourteen-family house! This was reported, and the policy of the Board was changed immediately.

After that, the Board or the Department determined the size of the meter that was to go in. They yanked this 4-inch meter out and put in one of the 1½-inch size. This gave the apartment house enough water for all purposes, and yet made the proper registration.

I think that is one of the prime reasons why the department should control the ownership of the meter. They control the waste, in other words. We all know that the ordinary dripping or a small stream will certainly not register on the large meter, because it does not register on the small mater, to some extent. In that way, we believe waste is eliminated to a very great degree.

In metering water for the fire department, we have found that very little water was used for that purpose compared with the total pumpage. With motorized engines and pumpers to get to the fire, there is hardly enough water used in the modern large city to make a great deal of difference.

We also meter private fire lines. If there happens to be a fire in the plant that is metered, we do not charge them for the water used. But if a fire line meter is being misused we penalize that.

James E. Gibson:[8] With reference to the few words Mr. Grobbel has just stated about fire lines, I want to tell you of an incident we had with the Southern Railroad on the water front.

[7] Assistant Secretary, Board of Water Commissioners, Detroit, Mich.

[8] President, American Water Works Association; Manager and Engineer, Water Department, Charleston, S. C.

On this particular water front property we had a 6-inch line, with about half a dozen hydrants operating on a very small charge for fire protection. I became suspicious after one or two visits to this property. While I did not actually find any leaking spigots or hydrants, I found evidence that they had been used. I could not learn that they had had a fire. So I put a 6-inch meter on this line and I notified the division superintendent of the Southern Railroad that we had done so; and that, if he had a fire, we would make no charge for any water passing through the meter; that that would be covered by the regular payment of the fire charge. I went on to say that, if the Underwriters demanded a test, and they used water for such a test, we would make no charge. But for any other water that passed through that meter I expected to render a bill, and I expected payment of that bill.

After installing the meter, we rendered a bill the month after for more than they had paid for water in two years under the old rate.

To make a long story short, they did not want any fire protection on the water front. People do not intend to deceive you. They think they are honest. It was discovered that when the darky who was unloading any kind of material on the ship got through, he went to the nearest hydrant and turned the valve, opened the valve and washed his hands or face. He did not even hesitate to take a shower bath in the summer when it was hot. The water department paid the bill.

William Luscombe:[9] I think the manufacturers could well devote more time and effort to making a meter for a combination service for just such a case where you furnish an industry with water and at the same time are obliged to furnish water for fire protection. These two requirements show a wide range in flow conditions, according to present machines.

We have found that the efficiency of the meters is very much below what they are rated to be, that is, under actual test. I suppose it is due to long time between uses, where the mechanical parts operate only once in a great while. We find in checking up that it is sometimes 86 per cent efficient. It seems to me that some improvement could be made if you just tried to perfect the machinery to get a better batting average, in cases where a utility furnishes such service.

[9] Vice President, Gary Heat, Light and Water Company, Gary, Ind.

C. A. Truman:[10] I would like to know if there is a standard straight charge annually on automatic sprinklers, where they are not metered. Is there just a flat rate charge for automatic sprinklers?

Chairman Gibson: I think it is the practice of all water departments and companies to make a charge for sprinkler service, but I do not think it is a standard charge. It varies a great deal.

Our practice in Charleston is to encourage the sprinkling systems. We make a flat minimum charge which is nominal. On those systems we put in no meter. In installing the sprinkler we have the sprinkler company certify there are no connections other than the sprinkler head. We inspect that occasionally to check up. As long as there are no outlets, and usually the insurance companies insist on there being no other outlets than the sprinkler heads, we put in no meter and make a minimum charge for that service. I think that in our case it is $50 for a connection not exceeding 5 inches. We make no connections larger than 5 inches.

James Sheahan:[11] In Memphis we own all our meters. We do not allow private ownership. We control the meters, even on the outside of the city. If they want to use water out there, we own the meter. We do not let them buy it.

I find Mr. Howson's statements check pretty nearly with what we find in Memphis.

I want to say a word about large meters on buildings. When we start to build a building the builder comes in and wants a large meter. He wants it to mix concrete in a hurry. Of course, after he leaves the job he leaves the meter in, and it makes the property owner pay more than if he had obtained a meter through our direction. We have stopped that. Whenever anybody asks for a larger meter, the owner must write a letter asking for it. If we think he is asking for too big a meter we tell him so. We keep the meters down as small as we can. One man wanted a 4-inch meter; we put in the $1\frac{1}{2}$ inch size. We do that frequently.

I have know of one 6-inch meter that we did not own. This was owned by a private concern and had 24 or 25 houses on it. This never registered anything and they never paid any water bill. The

[10] Superintendent, Northfield Land and Water Company, Colorado Springs, Colo.

[11] Superintendent, Water Works, Memphis, Tenn.

people all got their water through this meter free of charge. He wanted to know what he should do. We recommended a 1½-inch meter. That supplied the entire outfit and made the proper registration.

A. P. Michaels:[5] In the smaller cities this will be particularly applicable. We have a meter which is being put in a box with a very secure lock on it so that no one can get in but the meter reader. This is furnished with a flexible connection to each contractor or the city crews who do the repair work. Whenever it is attached to a fire hydrant they do have to obtain water. We check up on this pretty closely, so we do not have indiscrimate use of water without passing through the meter. This is only in the case of water being used for other purposes than fire fighting.

P. D. Rice:[12] Referring to the remarks of the last speaker, we also use a portable meter, principally for the use of contractors. We do not lock it, however. We found in both municipalities which we serve that it was a very simple matter to have the city council pass an ordinance making it a misdemeanor for any person to use the hydrant without written permission from the fire chief. That put it up to the police. So any person wanting to use water from the hydrants for other than fire purposes applies for permission from the fire chief. Then there is no trouble. I know of at least three instances where such an ordinance was passed and has proved satisfactory.

Chairman Gibson: In our municipality we find that the city employees are the violators of the ordinance.

The remarkable thing about Mr. Howson's paper is the analysis showing the water for fire protection. I think it averages 0.15 of 1 per cent of the total water pumped.

I do not keep a record of it, but I ordinarily estimate that we use about 1 per cent of our total pumpage for fire protection and street sweeping. I though that was a little bit low, but since hearing Mr. Howson's paper I am not so confident that I have not overestimated it.

Talking about the size of meters, two or three years ago Mr. Smith,

[12] Resident Manager, Sweetwater Water Company, National City, Calif.

manager of the Atlanta works, prepared a paper showing what he had done with data in the way of placing proper sized meters on services. It simply confirmed what Mr. Grobbel and other members said, that it does not pay to put a big meter in unless you have sufficient demand for it.

H. E. MOORE:[13] We had one case in which we had a large meter installed. We decided we were getting probably only about a third out of it that we should. We appealed to one of the meter manufacturers for a meter to use on 18 services. Sometime afterwards they came back with the meter. We put on a 3-inch compound. We discovered that it had two or three condensers that were not registering on the larger meter. The people did not think they had used the water which registered on the second meter. We sent an inspector along who finally convinced them that they were using the water as indicated.

They were using something close to a million gallons a month on that meter.

SECRETARY B. C. LITTLE: I did not hear all of Mr. Howson's paper, but I thought I understood him to draw conclusions, for instance, on the waste of water due to the use of one kind of service as compared with another. I wondered about the comparison he drew with lead caulked joints and the substitutes for lead. I understood him to say in the city that used the caulking other than lead for the joints in the cast iron pipe, the unaccounted for water was greater.

That was not my experience at all. It seems that our substitute for lead was just as tight, and in some cases even tighter, than the lead. I wonder if he actually drew that conclusion or if I misunderstood him.

L. R. HOWSON:[2] I really drew no conclusion as to joints. I say in my paper: "Relative to joint materials, no conclusions can well be drawn."

Taking all joints and putting them in two classes in these 44 towns, it so happened that 26 cities used lead joints exclusively—no substitutes; 18 cities used some substitutes, varying up to 40 or so per cent, with an average of about 20 per cent. Taking just those two groups,

[13] Dallas, Tex.

those that have lead substitutes and those that do not, the lead substitutes showed one or two per cent better than those that used lead exclusively.

I made a second comparison which shows the reverse. I took the seven plants, all of which account for less than 60 per cent of the water pumped, and compared them with the seven plants that showed the highest percentage, all above 85. There the lead joints showed better.

The seven cities which account for less than 60 per cent of the pumpage 37.7 per cent of lead substitutes, whereas those that account for 30 per cent more water, that is 89.5 per cent, have only 14 per cent of lead substitute. This would indicate from that comparison that the substitutes were not as good as the lead. Since one of those comparisons shows contrary to the other, I believe that no conclusion can well be drawn from these data alone, at least, as to which is the tighter material, and that the difference between those two groups in unaccounted for water is due to factors other than the joints.

L. A. QUIGLEY:[14] In the pitometer survey we had about a year and a half ago, we had less weakness in the joint substitutes for lead than we had in those laid with lead.

A. U. SANDERSON:[3] May I ask Mr. Howson what was the lowest percentage of unaccounted for water in all of these cities or towns? That is, what was the percentage in the cities that were 100 per cent metered?

L. R. HOWSON:[2] I got one that seemed to be authentic—and I could find no reason on its face to exclude it—of 97 per cent. That was an actual comparison of total summation of all meters with the Venturi meter. However, I am inclined to think that the difficulty lies in the fact that that Venturi meter was under-registering. That is my own personal opinion of this case. I doubt whether there is any system that can get 97 per cent results.

The average of the 7 highest plants was 89.5 per cent. There were 7 plants out of 44 that exceeded 85 that I think were authentic.

[14] Superintendent, Water Works, Fort Worth, Tex.

Chairman Gibson: Our record at Charleston, extending over eight years, is about 80 per cent. I have gone as high as 86 per cent, but I cannot maintain that figure. In that figure I have allowed nothing for fire fighting and street sprinkling, which is very small, or street sweeping, I should say rather than sprinkling. I neglect that because I have not tried to estimate it.

L. R. Howson:[2] In all of these figures this feature is eliminated. No deduction is made in any of these cases for water used for fire fighting.

Your percentage of 80 compares with the 73.5 per cent that did not come in the 89.5 per cent class; so you are about 5 per cent above the average.

Chairman Gibson: We find that to keep up to 80 per cent we had to watch our "p's" and "q's." I make an estimate every month on the water pumped, as measured by Venturi station meters. That is the denominator; and the numerator is the accounted for water as billed to the consumer.

L. M. Anderson:[15] I should like to ask whether in this computation the flush tank system is considered.

L. R. Howson:[2] In towns where it is used it only appears here in so far as those flush tanks are metered. I had experience in a city with about 150 flush tanks. The company undertook to supply those free of charge under an old franchise for about thirty years. The new franchise required them to pay for that water; so the company immediately put on meters. The immediate response was that the orifices in the flush tank drips operated at 500 gallons per day for a short time. Shortly after that the curve went up again. The next result was one or two replacements of the orifice. Today every one of those flush tanks is eliminated. The people could not pay the bill.

Wm. Luscombe:[9] In the case that showed 97 per cent of the water accounted for by customers' meters, how large a system was it? Approximately how many miles of mains were there, and what was the average pressure carried in that system?

[15] Controller, Department of Water Power, Los Angeles, Calif.

L. R. Howson:[2] Speaking from recollection, that occurred in a town with approximately 20 or 25 miles which carried from 50 to 60 pounds pressure.

Chairman Gibson: It makes a great difference whether your consumers are large or small. Between our pumping station and the city are a number of fertilizer plants, the United States Navy Yard, and several sawmills. I can account for the water between the plant and the city limits up to 97 per cent, month after month. But I have only large consumers in that region, such as the Standard Oil Co. Out of the total consumption they will probably take 25 per cent. So on that basis I can check very easily.

Of course, in that case I have a check on the accuracy or inaccuracy of the city limit meters with the station meters. If one happened to be under and the other over, that cuts down my percentage. But we try to keep those checked. Once in a while we find we used more water than we pumped; that is, we have accounted for more water than was acutally pumped. But we can always find the reason for that.

L. A. Day:[16] We do not have many meters in St. Louis. We have about 11,000 meters out of about 125,000 taps. However, those 11,000 meters represent approximately half our revenue. So it is apparent that one of the easy places to put your finger on in the case of loss of revenue is meters. As a result, we are making pitometer surveys of all our large meters. It is surprising to find how much they are off at times. In some instances they are off as high as 30 per cent.

Another thing we soon discovered was that a great many meters are oversize. Every summer we employ now about a half dozen college students to check up on the amount of water as shown by the meters. Then we can determine the size of the meter the customer ought to have. We keep about three trucks busy taking out large meters and putting in smaller ones.

So far as fire lines are concerned, we do not meter them. We have a very low rate for fire lines. But we find, especially where an automatic sprinkler system is used, that it is not necessary to put a meter on those fire lines, for those lines are practically all provided with an

[16] Water Commissioner, St. Louis, Mo.

alarm valve. If any water is used in the line the alarm sounds. The Underwriters keep our fire alarms in pretty good shape.

However, if any consumers are not members of the company that maintains the central offices, that is, the insurance companies, we insist on a check. If we find any unnecessary loss of water after checking and they continually do that, then we put in a regular velocity type meter on the fire line.

George W. Biggs, Jr.:[17] There is one factor which, in my opinion, has a very important bearing with respect to unaccounted for water, which perhaps was not dwelt on in the paper with as much emphasis as it deserves, and that is the proportion of the total amount of water delivered from the pump station which is sold through large meters; that is, 1 inch or larger in size. It has been my experience, in the operation of the water plants controlled by the American Water Works and Electric Company, that the relative proportion of water sold through large meters to the total is one of the principal factors with respect to the percentage of unaccounted for water. For instance, at Hopewell, Virginia, the Old Dominion Water Corporation sells to large industrial consumers possibly 90 per cent of the total amount of water pumped, and in that instance the percentage of unaccounted for water is only 2.5 per cent of the quantity leaving the pump station as measured by Venturi meters. At East St. Louis, where about 70 per cent of the total pumpage is consumed by approximately 20 consumers, the unaccounted for water is only 12.2 per cent. The average of all the "American" plants shows 24.2 per cent unaccounted for water, but where the output from the pump stations is not measured by Venturi meters this percentage is based on the plunger displacement of reciprocal pumps, so that in reality the unaccounted for water would be substantially less than the above percentage. In all instances where a very substantial proportion of the total output is sold through large meters, the unaccounted for water, in percentage, is much less than where the consumption is principally of a domestic character.

[17] Chief Engineer, American Water Works and Electric Company, New York, N. Y.

WATER WORKS PRACTICE[1]

A Summary of Current Experience

Question 1. Experiences in plants where the standard American Water Works Association rate structure with graduated service charge and stepped consumption charge is used. What has been the reaction on the part of the consumer, and, if unfavorable, has it persisted?

(Number of replies received, 64)

Number using this system and favoring it	19 cities, representing 29.7%
Number using this system, but public does not favor it	2 cities, representing 3.1%
Number who do not use this system	43 cities, representing 67.1%

Question 2. How do you finance water main extensions?

(Number of replies received, 64)

(a) By local improvements	16 cities, representing 25%
(b) By bonds	16 cities, representing 25%
(c) By earnings of water departments	12 cities, representing 18.75%
(d) By consumers	4 cities, representing 6.25%
(e) By guaranteeing 10% of cost	3 cities, representing 4.7%
(f) By company	3 cities, representing 4.7%
(g) By debenture	4 cities, representing 6.25%
(h) Assessing $1.00 per foot on each side which is relative cost of 6-inch main	1 city, representing 1.56%
(i) Question not answered by	5 cities, representing 7.8%

Question 3. How do you handle complaints on high water bills?

By testing meters and making allowances for over registration	33 cities, representing 51.56%
Showing consumer where water goes and adjusting if necessary	21 cities, representing 32.81%

[1] Data compiled by W. E. MacDonald, Chairman, Plant Management and Operation Division; City Water Works Engineer, Ottawa, Canada. Presented before the San Francisco Convention, June 11, 1928.

Notifying consumer when high consumption noticed	3 cities, representing 4.7%
Adjusting for immediate repairs	2 cities, representing 3.13%
Cut off at post	1 city, representing 1.55%
This question not answered in questionnaire by	4 cities, representing 6.25%

Question 4. (a) Do you attempt to prevent damage of meters by backing up of hot water? (b) If meters are damaged who pays for repairs of damaged meters?

(*a*) The question with respect to preventing damage of meters by backing up of hot water was answered as follows:

No damage	5 cities, representing 7.8%
No	35 cities, representing 54.7%
Yes	24 cities, representing 37.5%

(b) The question of the fixing of cost to damaged meters was answered as follows:

Consumer pays	45 cities, representing 70.31%
Company pays	10 cities, representing 15.63%
This question not answered by	9 cities, representing 14.06%

Question 5. (a) Are meters read monthly or quarterly? (b) Are bills made out monthly or quarterly? (c) Why?

(a) For monthly readings	37 cities, representing 57.81%
For quarterly readings	11 cities, representing 17.18%
For large monthly readings; small quarterly readings	15 cities, representing 23.45%
For semi-annual readings	1 city, representing 1.56%
(b) For monthly bills	29 cities, representing 45.3%
For quarterly bills	32 cities, representing 50%
For semi-annual bills	3 cities, representing 4.7%

(c) Monthly reading gives better control of meters.
Quarterly reading distributes the burden better.

Question 6. Do you think it best to leave the meter in the meter box when water is turned off, or to remove meter?

For removal	38 cities, representing 59.375%
To leave in	26 cities, representing 40.625%

Question 7. What system do you employ for the systematic testing, or removal, of large and small meters?

Municipalities making periodic tests	33 cities, representing 51.56%
The balance of municipalities have no definite period of testing meters	31 cities, representing 48.44%

Question 8. Which do you find most conducive to accurate reading—straight or round dials?

Favoring straight reading dial	32 cities, representing 50%
Favoring round reading dial	32 cities, representing 50%

Question 9. Are not straight reading dials more expensive to maintain?

Yes, undoubtedly more expensive to maintain	36 cities, representing 56.25%
No, find no difference	16 cities, representing 25.0%
No experience	12 cities, representing 18.75%

Question 10. Do you prefer meters placed in basements or at curbs? Why?

(a) Preferring meters installed at curb	32 cities, representing 50%
(b) Preferring installation in basements	27 cities, representing 42%
(c) Installing small meters in basements and large meters at curb	5 cities, representing 8%

Reasons for same:
(a) More accessible at curb.
(b) Prevents freezing in basement.

Question 11. (a) Do your meter readers wear uniforms? (b) Do you consider it a good idea?

(a) Uniformed meter readers	5 cities, representing 8%
Meter readers not in uniform	47 cities, representing 73.44%
Meter readers displaying badges	12 cities, representing 18.75%
(b) Now favoring uniforms	27 cities, representing 42%
Against uniforms	23 cities, representing 36%
Favoring badges	14 cities, representing 22%

Question 12. In water plants, where all water is sold by meter, should automatic sprinkler connections be metered when the sprinkler equipment is used by mercantile houses and with a dry pipe system?

The majority of municipalities are not in favor of metering automatic sprinkler connections when the sprinkler system is used by mercantile houses and with a dry pipe system, even in water plants where all water is sold by meter.

Against this practice	45 cities, representing 70.3%
For this practice	19 cities, representing 29.7%

Question 13. Grounding electrical circuits on water pipes: (a) What is the general experience from the water works point of view? (b) Has your experience warranted saying this practice is undesirable? (c) What other remedy do you suggest?

(a) No trouble experienced by grounding electrical circuits on water pipes	46 cities, representing 71.875%
Do not favor grounding electrical circuits on water pipes	16 cities, representing 25%
This question not answered by	2 cities, representing 3.125%

(b) Experience with this practice found most satisfactory	46 cities, representing 71.875%
Have found this practice undesirable	8 cities, representing 12.5%
This question not answered by	10 cities, representing 15.625%

(c) No other satisfactory suggestions offered.

Question 14. What has been your experience with flush meter valves in toilet fixtures?

Number of municipalities finding flush meter valves in toilet fixtures satisfactory	28 cities, representing 43.75%
Number of municipalities not favoring the use of flush meter valves in toilet fixtures	16 cities, representing 25%
Municipalities not having had experience with the above	20 cities, representing 31.25%

Question 15. Do you consider it good practice to provide a building with a fire line as large as the main on the street?

Against this practice	40 cities, representing 76.56%
In favor of this practice	15 cities, representing 23.44%

Question 16. Have you used copper service pipe for services, and, if so, what has been your experience? What sizes of pipe have you used?

Municipalities having had experience, and favoring copper pipe for services	26 cities, representing 40.625%

Municipalities having had no experience with copper pipe for services........................ 38 cities, representing 59.375%

Municipalities having used copper pipe report that sizes from ½ to 2 inches are very satisfactory.

Question 17. Do you make a charge for turning water on? How much?

(a) Number who make a charge for the turning on of water....... 19 cities, representing 29.69%
Number making no charge for same........................ 45 cities, representing 70.31%

(b) For the turning on of water which has been shut off for non-payment of water rates
A charge of $1.00 is made by... 22 cities, representing 44%
A charge of 0.50 is made by... 6 cities, representing 12%
A charge of 2.00 is made by... 3 cities, representing 6%

For merely turning on of water at any time $1.00 is the fee charged by.................... 19 cities, representing 38%

Question 18. Has the paving of streets decreased the leakage of mains and service lines?

Number believing that the paving of streets decrease the leakage of mains and service lines.......... 12 cities, representing 18.75%
The majority of municipalities do not believe that the paving of streets decreases the leakage of mains and service lines, as shown by the number of negative answers received by........................ 39 cities, representing 60.94%
This question was not answered by... 13 cities, representing 20.31%

Question 19. Water mains: Do you install centrifugally cast iron pipe in preference to the ordinary sand cast pipe?

Favoring centrifugally cast iron pipe. 25 cities, representing 39.06%
Not favoring centrifugally cast iron pipe............................ 37 cities, representing 57.81%
This question not answered by....... 2 cities, representing 3.13%

Question 20. (a) Do you make regular inspections of gate valves? (b) What do you consider an adequate inspection?

(a) (Number of replies received, 64)

Affirmative	47 cities, representing 74%
Negative	17 cities, representing 26%

(b) (Number of replies received, 50

Inspections should be yearly	24 cities, representing 48%
Inspections should be semi-annually	12 cities, representing 24%

The remainder have regular inspections, but do not state when.

Question 21. What kind of valve record do you consider essential?

70% of the cities keep records showing "Location, Date Installed, Number, Size, Turn," etc.

15% of the municipalities use maps or book records only.

15% of the municipalities do not keep records.

Question 22. What has been your experience with horizontal type of gate valves with beveled gears, versus vertical type with spur gears?

Of the 64 replies received:

30 municipalities have had no experience with horizontal gate valves, which represent 47% of the returns.

12 municipalities prefer the horizontal gate valve—which represent 19% of the returns—and a like number prefer the vertical gears.

10 municipalities show no preference, being satisfied to use either one. This represents 15% of the returns.

Question 23. Hydrants: Have you any organized system of inspection of fire hydrants to locate frozen ones during winter season.

Number which have no organized system of inspection of fire hydrants to locate frozen ones during winter season	30 cities, representing 46.875%
Number which have an organized system for inspecting fire hydrants, in order to locate frozen ones during winter season	34 cities, representing 53.125%

Question 24. Purification: (a) Do you have trouble with algae? (b) How do you overcome your algae troubles?

(a) There were 64 replies received to this question—35 cities, representing 54.69% show that they have experienced no trouble with algae; whereas 29 cities, representing 45.31%, have experienced trouble with algae.

(b) There were only 27 replies to this question. The chief method of overcoming this difficulty is by the use of copper sulphate, which is used by 23 cities, representing 85.2%; while the following methods are used in very small proportion.

By cleaning basin	1 city, representing 3.7%
By pre-chlorination	2 cities, representing 7.4%
By suction dredge to create turbidity before filtration	1 city, representing 3.7%

Question 25. Do you have phenol tastes in your water, and if so, what remedies have you found?

(Number of replies received, 64)

(a)	Municipalities having no phenol taste	55 cities, representing 89%
	Municipalities having phenol taste	7 cities, representing 11%
(b)	By filtration and aeration	2 cities, representing 40%
	By use of ammonia	1 city, representing 20%
	Flushing mains	1 city, representing 20%
	Draining phenol wastes into river	1 city, representing 20%

Question 26. How do you successfully treat small quantities of drinking water, so as to remove the phenol taste?

(Number of replies received, 64)

Municipalities who do not treat their water	61 cities, representing 95.2%
Super-chlorination followed by de-chlorination by use of sulphur dioxide	1 city, representing 1.6%
Laboratory tests to determine ammonia required	1 city, representing 1.6%
Alum and lime treatment	1 city, representing 1.6%

Question 27. What new maintenance equipment devices do you use to meet emergencies?

(Number of replies received, 64)

New equipment used by different municipalities as follows: portable gas pump and gasoline thawer, portable derrick on truck, portable air compressor, pipe pusher, electric leak locators, pipe locators, magnetic box finders, gate operating device on trucks, 3-inch centrifugal pump, geophone, aqua-phone, welding equipment, gasoline shovel, dipping needles, split sleeves, caterpillar cranes and trench diggers, flood lights.

Question 28. What data have you to compare the first cost, maintenance cost and the life of various materials used for water works services?

(Number of replies received, 64)

Cities where no record is kept.......... 41 cities, representing 64%

The remainder keep various data, such as records showing (a) installation and repairs, (b) initial cost of each service, (c) complete cost and maintenance of each service, (d) meters and hydrants, (e) complete cost system.

Question 29. What records do you consider essential in regard to service lines, that is, (a) book-keeping records? (b) meters? (c) test of meters?

(Number of replies received, 64)

Approximately 80% have a system of records for each service, meter and meter test. The majority of these use a card index system which gives, location, date of installation, cost of installation, maintenance and repairs.

Question 30. What system do you employ for plotting new water mains, valves and hydrants?

(Number of replies received, 53)

The large majority of the cities use a map system with the scale varying anywhere from 1 inch = 800 feet to 1 inch = 100 feet for a general map and for details, sectional maps with a scale varying from 1 inch = 100 feet to 1 inch = 20 feet.

Question 31. What size scale do you find best adapted for detail maps of the distribution system?

(Number of replies received, 52)

The following are the scales adapted by the different cities,—

1-inch = 400 feet....................	1 city,	representing 1.9%
1-inch = 300 feet....................	2 cities,	representing 3.85%
1-inch = 200 feet....................	4 cities,	representing 7.7%
1-inch = 120 feet....................	1 city,	representing 1.9%

1-inch = 100 feet	18 cities, representing	34.6%
1-inch = 80 feet	2 cities, representing	3.85%
1-inch = 60 feet	2 cities, representing	3.85%
1-inch = 50 feet	11 cities, representing	21.2%
1-inch = 40 feet	3 cities, representing	5.8%
1-inch = 30 feet	2 cities, representing	3.85%
1-inch = 20 feet	2 cities, representing	3.85%
1-inch = 10 feet	1 city, representing	1.9%
1½-inch = 1 foot	1 city, representing	1.9%
¼-inch = 1 foot	2 cities, representing	3.85%

SOME EXPERIMENTAL STUDIES OF EXTERNAL CORROSION OF COPPER AND BRASS SERVICE PIPE[1]

By K. H. Logan[2] and S. P. Ewing[3]

In recent years considerable interest has been manifested in the use of copper and brass pipe for water services. It is hoped by some that these materials will resist the action of the water which they must carry and of the soils to which they may be exposed. To assist in answering some of the questions which it received regarding these materials, the Bureau of Standards included in its soil-corrosion investigation samples of a number of copper-zinc alloy castings ranging from 96 to approximately 75 per cent copper. Some specimens of each alloy were attached to lead pipe to simulate the condition when a brass cock is inserted in a lead water service. Others were similarly connected to galvanized iron pipe, while a third group was connected to brass pipe containing approximately 40 per cent zinc. Figure 1 shows the initial appearance of the specimens. In all of these combinations, therefore, there was introduced the galvanic effect of the contact between two dissimilar metals. This effect would be expected to protect the brass castings and was the least in the case of those attached to the brass pipe.

In 1926 after the specimens had been buried in 47 soils for about two years, one-fourth of them was removed and the amount of corrosion determined. The results of this examination are discussed in some detail in Technologic Paper No. 368. As a general summary of the results, it may be said that the corrosion losses of these specimens were too small and too variable to enable us to draw conclusions as to the relative merits of the cast alloys. In most soils the average loss per unit area of the cast brass specimens was roughly a third of the losses of the brass nipples to which they were attached. It is not

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possible to state positively whether this difference was due to galvanic action protecting the specimens of higher copper content at the expense of the one containing more zinc; to the superior merits of cast as compared with drawn brass; or to the better corrosion resisting properties of the material with the higher copper content. Additional tests have been undertaken in which the factor of galvanic action between two connected metals has been eliminated.

Comparing the rates of corrosion of the brasses with those of iron and steel specimens in the same soils, we find a difference in the order of 10 to one in favor of the non-ferrous materials. This, it must be remembered, is based solely on the rates of loss of weight for the first two years of the experiment.

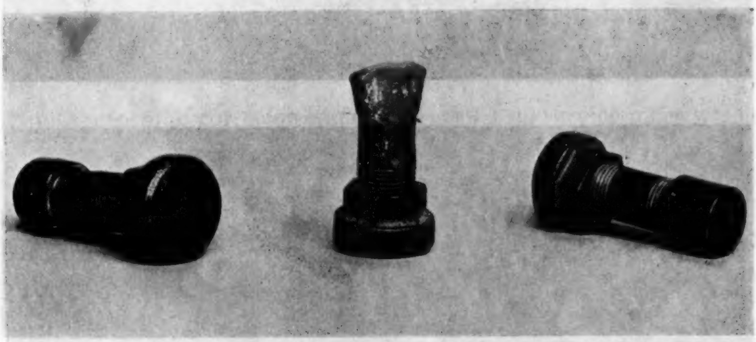

FIG. 1. THREE BRASS SOIL CORROSION SPECIMENS

The relative corrosiveness of different soils with respect to the two materials varied considerably. While a soil containing white alkali (sulphates) was very destructive to iron, it was not particularly corrosive with respect to brass. The loss of weight of brass in the soil most destructive to it was approximately half that of the ferrous materials in the same location.

In the case of the brass pipe containing approximately 40 per cent zinc there was in some soils an indication of selective corrosion, that is, a corrosion which removes the zinc more rapidly than the copper. If of sufficient magnitude this may result in a weakening of the pipe beyond the amount indicated by the loss of metal. This selective corrosion is in effect somewhat analogous to the pitting of steel, although the original contour of the pipe surface is retained as in the case of so-called graphitic corrosion of cast iron.

While the Bureau of Standards tests are too incomplete to justify final conclusions as to the merits of brass as a soil corrosion resisting material, the available data suggest that brasses containing high percentages of copper resist soil action somewhat better than the high zinc brasses and very much better than most ferrous materials.

FIG. 2. CORROSION OF PIPE WITH A BRONZE WELD

These two "panoramic" views show the whole circumference of a sand-cast iron pipe buried three years in a mixture of tidal marsh soil from Elizabeth, N. J., and muck from New Orleans, La. The upper photograph shows a brazed joint, the lower a portion of the pipe beginning 5 inches away from the joint.

CORROSION OF BRASS IN CONTACT WITH IRON

Questions have arisen occasionally regarding the use of brass in contact with iron. It has been feared by some that corrosion would result because of the difference of potential between these materials. Dr. Speller[4] in his book on corrosion cites a case of corrosion of a

[4] Corrosion Causes and Prevention, p. 516.

strainer used in oil wells where the galvanic action corroded the iron until some of the brass strainer inserts fell out. On the other hand, it has been common practice for many years to screw brass cocks into cast iron water mains and very few cases of corrosion on account of this practice have been reported. There are some cases of rust collecting on the end of the cock inside the pipe indicating, perhaps, galvanic action on that side.

A few years ago the Bureau of Standards buried a number of specimens of cast iron pipe having bronze welded joints. The condition of one of these joints buried for about three years is shown in figure 2. It will be noted that the surface of the pipe shows considerable corrosion, but there is no marked concentration of this corrosion near the joint as would be expected if the corrosive attack were accelerated by the bronze weld.

ELECTROLYSIS TESTS OF COPPER AND BRASS PIPES

Another form of corrosion sometimes occurs on service pipes which is very serious, and destroys such pipes in a fraction of the time they would last if exposed only to the action of clean soil. This is commonly referred to as electrolysis. There is, of course, on the part of those who have to cope with this trouble a desire to find a material which is not destroyed by electrolytic action. The question has been raised as to whether copper or brass is such a material.

Before discussing the results of the Bureau's study of this question it seems desirable to call attention to a few well-known but often forgotten facts regarding stray current electrolysis. This form of corrosion is caused by electric current flowing from the pipe to the soil and this rarely occurs except when the pipe is quite near another metallic structure or an underground water course and usually only in the neighborhood of a street railway powerhouse or substation. While under unusual circumstances it is quite possible for electrolytic corrosion to occur at locations remote from substations, much of the corrosion found under such conditions and attributed to stray currents is actually caused by local soil action. Only a very small portion of the water services of a city is exposed to electrolysis and the question of whether a pipe will resist electrolysis is, except in special cases, of no great importance. Since the locations where electrolysis is apt to occur are usually known at least in a general way, it would seem best to give these locations special and separate consideration.

In the case of iron and steel pipe, it has been found that the rate of

TABLE 1

Results on electrolysis test of non-ferrous metals

NUMBER	PERCENTAGE OF CONSTITUENTS Cu	Zn	Pb	Fe	RESISTIVITY IN OHMS PER FOOT-POUND $\times 10^{-6}$	CORROSION LOSS	ELECTROLYTIC LOSS	COEFFICIENT OF CORROSION
						grams	*grams*	
1	99.96	(phosphorus 0.020)			4.15	0.16	1.28*	1.28
							1.29	1.30
						0.17	5.78†	1.20
							5.68	1.23
						0.08	3.01‡	1.32
							3.11	
2	99.94	(oxygen 0.03)			3.20	0.15	1.27*	1.27
							1.21	1.21
						0.12	5.62†	1.17
							5.51	1.15
						0.02	2.84‡	1.36
							2.95	1.30
3	99.962				3.22	0.21	1.24*	1.24
							1.25	1.25
						0.16	5.87†	1.22
							5.53	1.15
						0.04	2.66‡	1.17
							2.89	1.27
4	99.965	(phosphorus 0.012)			3.77	0.23	1.19*	1.19
							1.31	1.32
						0.18	5.95†	1.24
							5.67	1.18
						0.07	2.58‡	1.14
							2.68	1.17
5	99.953	(phosphorus 0.008)			3.49	0.14	1.15*	1.15
							1.23	1.23
						0.18	5.63†	1.17
							5.56	1.16
						0.04	2.54‡	1.12
							2.88	1.27

*** Surface soil from Bureau of Standards grounds with 30 per cent moisture added. 3.7 milliamperes per square foot. Effective voltage about 0.16 volt per cell for 1689 hours.**

† Same soil with 30 per moisture added, 18.5 milliamperes per square foot. Effective voltage about 0.4 volts per cell for 1689 hours.

‡ Sand with 5 per cent moisture added. 120 milliamperes per square foot at first. Fell to 12 milliamperes per square foot. Average 23 milliamperes per square foot. Effective voltage per cell 3 volts which soon was raised to 9 volts.

Chemical analyses were furnished by the manufacturers who supplied the materials.

TABLE 1—*Continued*

NUMBER	PERCENTAGE OF CONSTITUENTS				RESISTIVITY IN OHMS PER FOOT-POUND × 10⁻⁵	CORROSION LOSS	ELECTROLYTIC LOSS	COEFFICIENT OF CORROSION
	Cu	Zn	Pb	Fe				
						grams	*grams*	
6	84.56	15.35	0.03	0.04	8.80	0.20	1.13*	1.13
							1.24	1.23
						0.19	5.17†	1.07
							5.18	1.07
						0.06	2.34‡	1.02
							2.39	1.04
7	79.99	19.94	0.03	0.04	9.64	0.18	1.07*	1.06
							1.08	1.07
						0.26	5.42†	1.12
							5.05	1.04
						0.05	2.14‡	0.94
							2.09	0.91
8	67.57	31.84	0.57	0.02	11.09	0.14	1.18*	1.16
							1.09	1.06
						0.19	4.99†	1.01
							5.10	1.03
						0.08	2.55‡	1.09
							2.51	
9	61.18	38.54	0.26	0.02	11.05	0.17	0.98*	0.95
							1.00	0.99
						0.20	4.69†	0.96
							4.63	0.95
						0.11	2.40‡	1.03
							2.37	1.02
10	60.00	39.8	0.10	0.04	10.92	0.20	0.92*	0.91
							1.05	1.04
						0.18	4.80†	0.99
							4.62	0.96
						0.12	2.29‡	1.00
							2.35	1.02
11	73.90	5.21	0.00	0.10	50.8	0.11	1.29*	1.32
		(Nickel 20.18 per cent)					1.21	1.22
						0.15	7.05†	1.50
							6.75	1.43
						0.05	2.12‡	1.17
							2.75	1.23
12	95.44	0.05	(Si 3.17)		46.6	0.29	1.20*	1.24
			(Mn 1.10)				1.22	1.26
						0.29	6.43†	1.38
							5.33	1.14
						0.12	2.76‡	1.25
							2.37	1.07

electrolytic corrosion is roughly proportional to the current leaving the pipe, although the character of the soil and density of current discharge have some effects on the rate and character of corrosion.

The Bureau of Standards has had the coöperation of the American Brass Company and the Mueller Brass Company in the study of the electrolytic corrosion of copper and brass service pipe. After some preliminary experiments, samples of 12 non-ferrous materials were tested under three conditions and the coefficients of electrolytic corrosion determined. The results of these tests are given in table 1.

This coefficient is the ratio of the actual loss caused by the discharge of a given quantity of electricity to the theoretical loss as indicated by Faraday's law which says that the loss depends on the quantity of electricity and the electrochemical equivalent weight of the metal. Thus the theoretical loss of ferrous iron is approximately 1.042 grams per ampere hour, the loss of cupric copper 1.186 grams per ampere hour and of zinc 1.219 grams per ampere hour, while that of brass depends on the relative amounts of copper and zinc.

In computing the results given in the table we have assumed the valence of each of the ingredients of the alloy to be two, with the exception of silicon which has been taken as four. We have assumed also that the current divides between the elements in proportion to the equivalent amounts present. This assumption is not correct, but it is nearly enough true for the purposes of this paper. The assumption that the copper is bivalent is, however, open to question. In work done in the Metallurgical Division of the Bureau on accelerated corrosion tests by the electrolytic method, better agreement has been found between actual losses and those calculated by Faraday's law when the copper was assumed to pass into solution in monovalent form. Until our results are checked by further tests the numerical values must therefore be considered as tentative.

To determine the coefficient of corrosion under a given condition a specimen of each material was placed in the center of an iron cylinder 6 inches high and 6 inches in diameter. The specimens with a few exceptions were cut from $\frac{3}{4}$ inch (iron-pipe-size) pipe. The lower end of the iron cylinder was closed by a piece of insulating material and the cylinder was filled with moist earth or sand, care being taken to keep the moisture content uniform. The central copper or brass pipe was made anodic and the iron cylinder cathodic, the voltage being so regulated as to secure a predetermined rate of current discharge. To distinguish between electrolytic and soil action a control speci-

men was placed in the soil near one side of the cylinder and screened from the current by surrounding it with a cylinder of copper screen wire about 2 inches in diameter. This screen shunted the current around the control specimen but allowed free diffusion of the soil moisture and gases. To reduce the loss of moisture on account of evaporation the exposed surface of the soil was covered by a thin layer of paraffin.

Two specimens of each material were subjected to each electrolytic test condition, but as two of the soils in the tests were identical, one control specimen of each material was deemed sufficient for each current density. The current was regulated by a resistance in series with the specimens and the total ampere-hours determined by means of a copper voltameter. Figure 3 shows the arrangement of the apparatus.

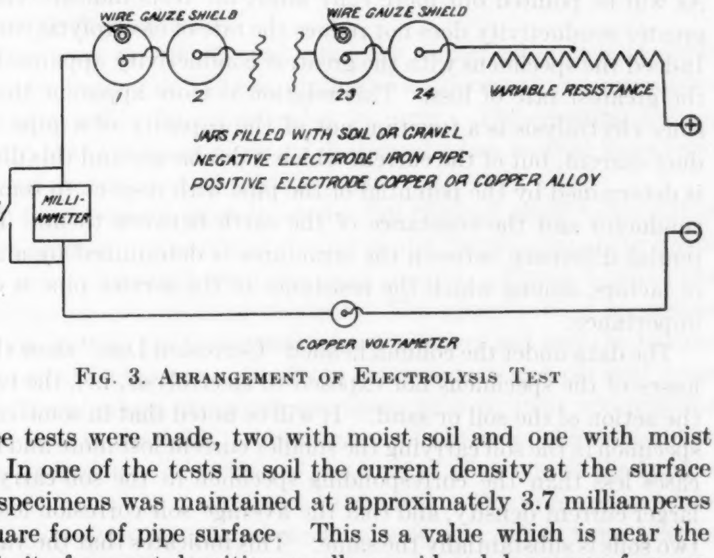

FIG. 3. ARRANGEMENT OF ELECTROLYSIS TEST

Three tests were made, two with moist soil and one with moist sand. In one of the tests in soil the current density at the surface of the specimens was maintained at approximately 3.7 milliamperes per square foot of pipe surface. This is a value which is near the lower limit of current densities usually considered dangerous from an electrolysis standpoint.

The voltage drop across a single cell was approximately 0.75 volt, a value not infrequently encountered in electrolysis surveys. This was opposed by an e.m.f. of about 0.6 volt caused by the galvanic action between iron and copper. The second test in soils was run at a current density of about 18.5 milliamperes per square foot, a value which represents severe electrolysis conditions although values several times as great have been observed under actual operating con-

ditions. In both of the above tests the soil was so moist as to afford an approximately uniform contact with the pipe and consequently a fairly uniform distribution of the corrosion. These tests continued 1689 hours. In the third test sand was used to secure a condition of nonuniform discharge and high current density. The experiment ran 619 hours starting with a current density of 120 milliamperes per square foot. This current density could not be maintained and it gradually decreased to 12 milliamperes per square foot. Table 1 shows the data for the three tests.

The data on the composition of the specimens were furnished by the manufacturers supplying the materials.

The data on the electrical resistivity of the specimens indicate that all but two of them are superior to steel as conductors of electricity. As will be pointed out more fully later, the tests indicate that this greater conductivity does not reduce the rate of electrolytic corrosion. Indeed the specimens with the greatest conductivity apparently have the greatest rate of loss. This relation is more apparent than real, since electrolysis is a function not of the capacity of a pipe to conduct current, but of the current which it discharges and this discharge is determined by the potential of the pipe with respect to some other conductor and the resistance of the earth between them. The potential difference between the structures is determined by a number of factors, among which the resistance of the service pipe is of little importance.

The data under the column headed "Corrosion Loss" show the total losses of the specimens not exposed to electrolysis, i.e., the extent of the action of the soil or sand. It will be noted that in some cases the specimen in the soil carrying the smaller current lost more and in other cases less than the corresponding specimen in the soil carrying the larger current density, and that the average soil corrosion loss in the two soils is substantially the same. This indicates that the variations in losses of the corresponding specimens is accidental and that the screens which surrounded them were effective in preventing corrosion by the current in the soil. The third value for each material is different because this specimen was in sand and was exposed for a much shorter period. The soil-corrosion losses are too small and the test continued too short a time to justify positive conclusions as to the relative merits of the materials used. Apparently some materials resist the action of the soil used in the test somewhat better than others.

The electrolytic loss is determined by subtracting the loss caused by soil corrosion from the total loss of the specimen exposed to electrolysis.

The column showing the coefficient of corrosion is of greatest interest. The determination of this figure has been previously discussed. The coefficient for each specimen is given in order that the variation between two specimens exposed to the same conditions may be noted and compared with the variation in the coefficients for different materials. It will be noted that in no case is the coefficient of corrosion much below unity. This means that the actual loss caused by the discharge of current is approximately what would be predicted from the atomic weight and valence of the components of the alloy and that for a given amount of current discharged the losses are about the same as would be sustained by iron or steel under similar electrolysis conditions.

As has been previously indicated the numerical values of these coefficients depend on the assumption of a valency of two for copper and may possibly be considerably in error. The essential fact is, however, that the brass pipes are destroyed when current flows from them just as iron or steel pipes are.

In many instances pipes in service fail through small holes rather than on account of loss of metal; that is, the distribution of the corrosion is more important than the total amount. Figure 4 shows the electrolysis specimens after the test. The upper row of specimens were subjected to the low current density in wet soil and the bottom row to rather high current density in sand containing 5 per cent moisture. The numbers above the specimens refer to their composition as indicated in the table. Comparison of the rows shows that the type of corrosion is a function of the kind of alloy and of the type of contact between the specimens and the soil. The appearance of the specimens containing a large percentage of zinc differs from that of the others because the corrosion of the former is selective leaving the contour of the surface unchanged. That the corrosion of these specimens is irregular is indicated in figure 5 which shows micrographs of a cross section of four specimens.

The magnification in each of the micrographs is 100 times. Specimen A shows the type of corrosion of an alloy of approximately 60 per cent copper and 40 per cent zinc when the specimen discharged current at the average rate of 2.8 milliamperes per square foot. The surrounding medium was moist sand and gravel and the current den-

sity at the points of discharge of current was considerably greater than the average rate. The specimen appeared spotted when cleaned but there was no indication of pits. The micrograph shows dezincifi-

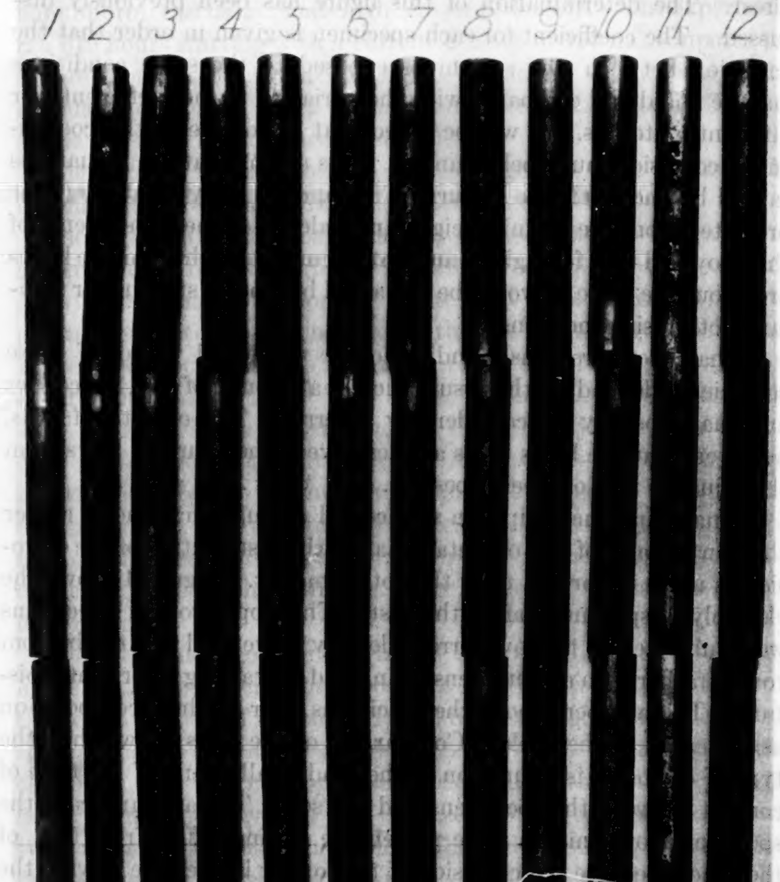

FIG. 4. APPEARANCE OF SPECIMENS AFTER TEST

cation or selective corrosion similar to that encountered in the corrosion of Muntz metal not exposed to electrolysis.[5] Micrographs B,

[5] See Bureau of Standards Technologic Paper No. 103, Typical Cases of Deterioration of Muntz Metals by Selective Corrosion.

C, and D show the types of corrosion of specimens discharging current at the average rate of 18.5 milliamperes per square foot into wet soil.

The surface of specimen B was smooth but marked by copper colored spots. To the unaided eye, the cross section of the speci-

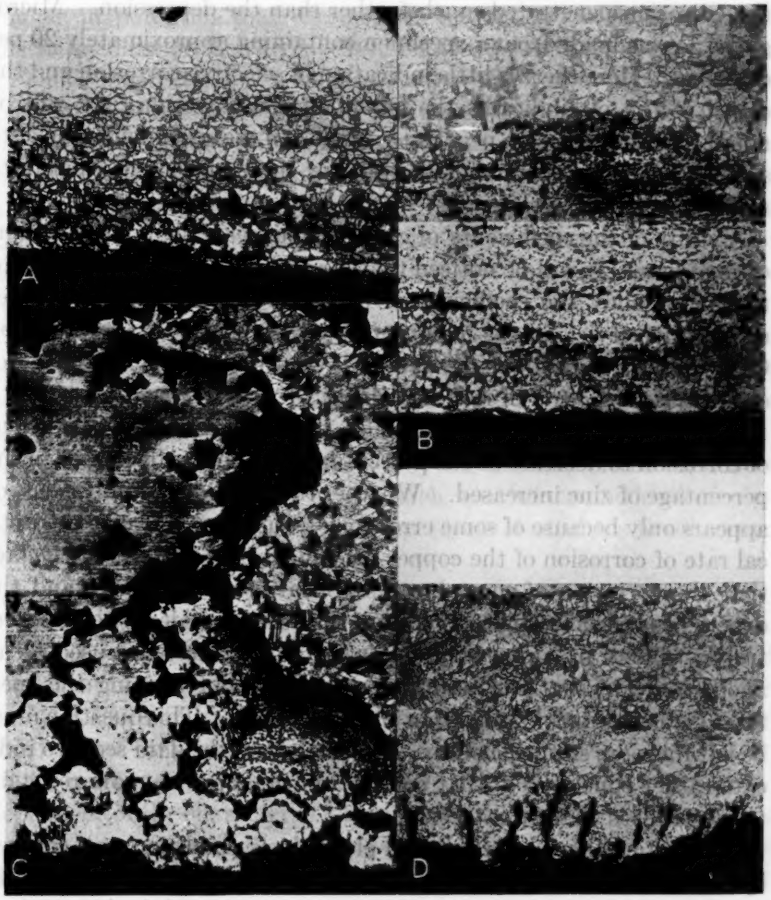

FIG. 5. SECTIONS OF SPECIMENS OF MUNTZ METAL AND OTHER BRASSES SHOWING PENETRATION OF CORROSION. (MAGNIFICATION × 52)

A, 40 per cent zinc; current density 2.8 m.a. per square foot. *B*, 38.5 per cent zinc; current density 18.5 m.a. per square foot. *C*, 31.6 per cent zinc; current density 18.5 m.a. per square foot. *D*, 19.9 per cent zinc; current density 18.5 m.a. per square foot.

men shows at certain locations, copper colored streaks entirely surrounded by brass colored areas. Micrograph B shows that there has been a change in the structure of the metal for a considerable distance below the surface. Micrograph C shows the structure of corrosion spot in a brass containing about 31 per cent zinc. Some of the metal was removed from the surface leaving slight depressions, but the corrosion penetrated much further than the depression. Micrograph D was made from a specimen containing approximately 20 per cent zinc. Here there is little indication of selective corrosion and the depth of the pit indicates the extent of the corrosion. It will be noted that the corrosion penetrates further in the specimens subject to selective corrosion although to the eye these specimens appear to suffer less.

A study of the coefficients of corrosion suggests some rather interesting ideas. It will be noticed that for all kinds of specimens except the nickel alloy the coefficient of corrosion is greater for the lower current density. This is in conformity with the results obtained by Ganz[6] and by the Bureau of Standards[7] in studies of the coefficient of electrolytic corrosion of iron and steel.

The data tabulated seem to show a tendency for the coefficient of corrosion to decrease as the percentage of copper is decreased or the percentage of zinc increased. Whether this relation actually exists or appears only because of some erroneous assumption as to the theoretical rate of corrosion of the copper-zinc alloys is not clear, but the fact that the corrosion of some brasses appears to be selective and the experience of electro-platers of brass that the brass deposited by electrolysis differs in copper content from that of the brass used as an anode indicate that the assumption made in determining the coefficient of corrosion of brass is not strictly correct. This question must be left for more scientific study. Nevertheless, the data seem to indicate rather conclusively that copper and brass are no more resistant to electrolysis than iron or steel.

In practice there may arise an electrolysis condition not covered by the data given above. Since it is common practice for a city water department to own the service pipe up to the curb, while the property holder owns the part from the curb to the house, it may happen that one section of the service pipe is of copper or brass while the other sec-

[6] Proc. A. I. E. E., vol. 31, p. 1167.

[7] Bureau of Standards Technologic Paper No. 259.

tion is of steel. Usually the discharge of current will occur largely at the point where the service is nearest the conductor causing the discharge, e.g., where the service crosses the street car track or the gas main. In some cases, however, the discharge may be to a parallel conductor, say an iron gas service pipe. Under such circumstances the iron part of the water service will be approximately 0.6 volt higher in potential than the copper section and consequently will discharge most of the current and so suffer most of the corrosion.

This is illustrated by an experiment in which a piece of copper and a piece of steel pipe were connected in parallel and made anodic to an iron cathode in soil. The two anodes had the same areas, but the copper lost 0.28 gram while there was a loss of 4.57 grams at the iron anode. A second cell in series with the one above mentioned and thus carrying the same current had a single iron anode which lost 4.97 grams or approximately the sum of the losses of the two anodes which were in parallel.

It appears, therefore, that a condition may exist under which a copper service pipe resists electrolysis not because of its inherently superior qualities, but because it is protected by the iron to which it is connected. However, as was said before, usually the point of discharge of current will be controlled by the position of the conductor receiving the discharge and under such conditions one kind of pipe is substantially as good as another so far as electrolysis is concerned if of equal wall thickness.

SUMMARY

Data now available while incomplete indicate in a general way that copper and brass pipe high in copper withstand most soil action very well. Little is to be feared from galvanic action on the outside of the pipe caused by connecting steel to copper or brass in most soils. Under most electrolysis conditions the rate of corrosion is nearly independent of the character of the pipe material and the life of a water service pipe exposed to electrolysis will depend largely upon the thickness of the pipe wall.

PREPARATION OF THE ORTHO-TOLIDINE REAGENT FOR FREE CHLORINE

By C. S. Boruff,[1] S. J. Vellenga[2] and R. H. Phelps[3]

In reviewing the literature and in conversing with those using the ortho-tolidine test for free chlorine, it is noted that there are a number of methods in use for the preparation of the o-tolidine reagent. Even among those using the same method different results are noted. It is the purpose of this paper to review briefly the more promising methods of reagent preparation and to outline the effect of acid concentration and thermal changes on the solubility of the reagent.

It is quite generally conceded that the reagent should be prepared by using hydrochloric acid. Ellms and Hauser (Ind. Eng. Chem., 5: 915 and 5: 1030) found that acetic acid gave variations in colors with waters of different degrees of alkalinity. They also noted that a sulphuric acid solution of ortho-tolidine was more difficult to prepare and did not seem to be as sensitive to free chlorine as the HCl solution.

In the 1917 and 1920 editions of Standard Methods of Water Analysis specifications are given for dissolving 1 gram of o-tolidine in one liter of 10 per cent HCl by weight. This would mean 236 cc. of concentrated HCl (35 per cent) in a liter of solution. More recent editions specify 1 gram of o-tolidine in 10 per cent HCl by volume. This would mean using 100 cc. of concentrated HCl instead of 236 cc. On the basis of the directions as given in the 1917 and 1920 editions of Standard Methods, Roake (Ind. Eng. Chem., 17: 257) noted difficulties in preparing the reagent and published another method for its preparation. In criticizing Roake's method, Theriault (Public Health Reports, 42: 670) offers a method of preparing the reagent, but seemingly fails to note that Roake was trying to dissolve 1 gram of o-tolidine by using 236 cc. of concentrated HCl. Theriault uses only 100 cc. of the acid. By using either Roake's or Theriault's method, the authors have found it impossible

[1] Associate Professor in Chemistry, Monmouth College, Monmouth, Ill.
[2] Student Chemist, Monmouth College, 1927, Monmouth, Ill.
[3] Student Chemist, Monmouth College, 1928, Monmouth, Ill.

to prepare an ortho-tolidine solution that will not crystallize out on standing if over 178 cc. of concentrated HCl (35 per cent) per liter is used and the temperature remains around 23°C. Several other methods of reagent preparation were tried, but none of them were successful in getting the o-tolidine reagent into solution immediately. Theriault's method (Pub. Health Report, 42: 670) works well for dissolving o-tolidine in various strengths of HCl, but, as stated above, if over 178 cc. of the concentrated HCl is present per liter, crystals will be thrown down in time.

It is quite advisable in some cases, such as in determining the amount of free chlorine in sewage and other highly buffered solutions, to have an o-tolidine reagent solution of a high acid concentration. Such solutions however are difficult to prepare due to the insolubility of o-tolidine hydrochloride in concentrated HCl. Buswell and Boruff in a Report of Committee No. 1 on Standard Methods, as published in THE JOURNAL, 17: 121, found that o-tolidine is soluble in dilute HCl but not in concentrated HCl. They state: "This is undoubtedly due to the formation of o-tolidine hydrochloride . . . ." The present authors by using Theriault's method of reagent preparation were able to dissolve at room temperatures 1 gram of o-tolidine in a liter of solution containing 240 cc. of concentrated HCl. This solution on standing threw out crystals in two days. Such determinations were repeated using lesser amounts of HCl to determine the maxium HCl concentration at which the reagent would remain in solution. It was often noted that solutions could be prepared using from 178 to 190 cc. of concentrated HCl which would remain in solution for weeks at 23°C. However, if these solutions were cooled crystals were thrown out of solution which would not go back into solution at the original temperature of 23°. The addition of a crystal of o-tolidine on shaking would not throw down crystals as long as the temperature remained at 23°C. This tends to prove that the solution was not supersaturated. These changes in the reagent took place very slowly, so in dealing with them constant temperatures had to be maintained over a considerable period of time. In general the temperature variations were within 1°C. plus or minus from the mean temperature. At 23.6°C., which is about the average laboratory temperature, it is possible to get and to keep 1 gram of o-tolidine completely dissolved in a liter of solution containing 178 cc. of concentrated HCl. At 27°C. 1 gram of the reagent may be completely dissolved in a liter of solution containing 198 cc. of the concentrated

acid. The investigators worked with solutions up to 224 cc. of concentrated HCl per liter and found that 1 gram of o-tolidine remained in solution at least one week at 32°C. However if any of these solutions containing more than 178 cc. of the concentrated HCl per liter are placed at laboratory temperature (23°) they soon throw out crystals. The solution containing 224 cc. of the acid per liter threw out crystals in four days. It took longer for the solutions of lower acid concentration. Temperature and HCl concentration seem to be the controlling factors in the preparation of solutions of o-tolidine.

The investigators tried to prepare solutions of higher acid concentration by using mixtures of concentrated HCl and H_2SO_4. Apparently it is impossible to prepare solutions of higher hydrogen ion concentration by using mixed acids.

The authors have found Theriault's method for the preparation of the o-tolidine reagent to be the most rapid and reliable. For most free chlorine determinations the regular reagent (10 per cent HCl by volume) is all right. If greater acid concentrations are desirable it would seem advisable for those working in the average laboratory with the usual temperature changes to keep the acid concentration somewhat below 178 cc. per liter. In a laboratory test using 150 cc. of concentrated HCl per liter no crystals came out when exposed to a temperature of 14° for a period of four days. If it is known that a temperature of over 23°C. can be consistantly maintained higher concentrations of acid could undoubtedly be used with very desirable results.

In all the investigations the orth-tolidine used was the C. P. product No. 249 of Eastman Kodak Co. This reagent had a melting point of 128.5°C.

A NEW INDICATOR FOR CHLORINE

By Knut Alfthan[1] and Translated by Alec. C. Jarvis[2]

Translators Note: In ortho-tolidin we have a very useful and widely used tool, but it is not impossible that in dimethyl-p-phenylenediaminechlorinehydrate we have a better. It is in the hope that some of my chemist fellow members will take the matter up that I venture to submit this translation of a short account of the very useful work done on this indicator by Mr. Alfthan at Helsingfors.

Mr. Alfthan's method is excellent and delicate for laboratory use, but for general use in unskilled hands its two weaknesses are its sensitiveness to iron and the definite pH range required. If further research will eliminate these, so that the method is universally applicable, and can be used by the layman as well as the technician, it will lend itself to the making up of simplified outfits in the lines of the American La Motte and Wallace and Tiernan, the English B.D.H., the German Folien Kolorimeter and the like.

It will be observed that Mr. Alfthan in dealing with benzidine and ortho-tolidin has considered them chiefly in their blue color range, being presumably most interested in an indicator producing a color other than yellow, thus avoiding the difficulty due to the natural color of some surface waters.

For fuller accounts of the iodide starch and ortho-tolidin methods reference may be made to the careful work of Buswell and Boruff, described by them in vol. 14, No. 5, 1925, of The Journal; to reprint No. 1145 U. S. Treasury Dept. Health Reports by Theriault; to the A. P. H. A. Standards, 1927, and the bibliographies given in the respective papers.

In the sterilizing of drinking water chlorine gas and hypochlorite are almost universally used, and the amount of free chlorine required for this purpose varies according to the nature and quality of the water from 0.2 to 2.0 mgm. per liter. On adding the chlorine to the water a considerable proportion is quickly reduced by impurities present, and to ensure sterilization sufficient should be added, so that ten minutes afterwards the chlorine has not dropped lower than 0.1 mgm. per liter. Naturally with the further passage of time the chlorine content becomes still smaller and eventually disappears.

When it is necessary qualitatively and quantitatively to determine the presence of these very small quantities of free chlorine, one needs

[1] Diplomingenior, Chief Chemist to Helsingfors, City Waterworks, Finland.

[2] Water Engineer, Copenhagen, Denmark.

a delicate indicator. Such are (1) potassium-iodide with starch, (2) benzidine, (3) ortho-tolidin and (4) the one I now use—dimethyl-p-phenylenediaminechlorinehydrate. I should mention that, upon completion of my work on this indicator, I observed a reference to work on the same reagent done by Kolthoff[3] in Holland in 1926. The short reference I saw, however, contained no information beyond that the reagent used would indicate 0.03 mgm. per liter Cl.

Just a few words regarding the three first named indicators before going on to the fourth.

POTASSIUM-IODIDE AND STARCH

This reagent exhibits with Cl a beautiful blue color, but it is not so delicate an indicator as those that follow. According to Bergman (Kemistsamfundets Meddelanden 1916: Sterilisation av drick-svatten med hypokloriter) this indicator under the most favorable conditions will show 0.05 mgm. per liter Cl.[4] In addition to potassium-iodide's lack of sensitiveness compared with the others, it has also the disadvantage that, when titrating with very weak solutions of $Na_2S_2O_3$, it is difficult to determine the end point. A further circumstance against KI is the instability of weak $Na_2S_2O_3$ solutions.

BENZIDINE ($NH_2 \cdot C_6H_4 \cdot C_6H_4 \cdot NH_2$)

According to Olszewski (Dresden) this reagent can show 0.02 mgm. per liter Cl and forms a blue color, which, however, is only produced when the sample has a pH after addition of an acid solution of the reagent, between 3.7 and 4.9. With greater acidity the color becomes greenish, changing with still increasing acidity to yellow. The blue color produced by this indicator lasts but a short while.

Because of the above characteristics I do not consider benzidine a suitable reagent for Cl for quantitative determinations.

ORTHO-TOLIDIN ($NH_2 \cdot C_6H_3(CH_3) \cdot (CH_3) \cdot C_6H_3 \cdot NH_2$)

In acid solution ortho-tolidin produces a yellow color in the presence of Cl. According to information 0.02 to 0.01 mgm. per liter Cl can be observed.[5] With colored waters, however, it is presumably difficult to determine small quantities of chlorine.

[3] See page 651, vol. 18, of THE JOURNAL. (Translator.)
[4] 0.005 according to Buswell and Boruff. (Translator.)
[5] 0.005 according to Buswell and Boruff. (Translator.)

As ortho-tolidin's formation is the same as benzidine's with the difference that two hydrogen atoms are replaced by CH_3 radicals, it would seem reasonable to group these two reagents together. As mentioned, both, in the presence of Cl, produce a yellow color in acid solution. When examining this reagent I found that ortho-tolidin can also give a blue color; this happens at a pH between 4 and 4.6, the color becoming greenish with increasing acidity.

As shown, therefore, both benzidine and ortho-tolidin behave alike with the difference that the blue color with ortho-tolidin is produced within very much smaller limits of pH.

DIMETHYL-P-PHENYLENEDIAMINECHLORINEHYDRATE

$$(NH_2 \cdot C_6H_4 \cdot N \cdot (CH_3)_2HCl)$$

This reagent produces with Cl a beautiful red color. One can see and determine 0.01 mgm. per liter Cl when using 100 cm.^{3} of water.

Even this indicator, however, has its disadvantage in that it is affected by iron ($Fe^{\cdot\cdot\cdot}$), 0.1 mgm. per liter however does not interfere, provided one does not let the sample stand longer than the two minutes which are necessary (especially when the water is cold) to obtain full color intensity after addition of the reagent. The time factor applies also to benzidine and ortho-tolidin, which however require five minutes.

In my experiments I used 1 cm.^{3} 0.1 per cent solution to a 100 cm.^{3} water sample. The indicator gives a color of the same depth and tone with a considerable variation of pH, viz. between 2.6 and 3.4.

The titratable acidity can vary in other words from about 5 to 25 cc. N/10 HCl per liter as against +1.0 to −3 for benzidine and +0.5 to −1.0 for ortho-tolidin.[6]

The color produced by dimethyl-p-phenylenediamine and chlorine is of the same tone as methyl red (dimethylaminoazobenzol-o-carbonicacid) in acid solution. I have therefore worked out the following quantitative analytical method.

By experiment it was found that 1 cm.^{3} 0.00115 per cent methyl red (Kahlbaum) in 100 cm.^{3} acidified water gave the same color as 0.01 mgm. Cl in 100 cm.^{3} water (= 0.1 mgm. per liter). Such dilute solutions of methyl red, however, are difficult to make. I have therefore adopted a 0.115 per cent stock solution. The dye is dissolved in 5 cm.^{3} normal NaOH and diluted to 100 cm.^{3} Even the

[6] Working on the blue color range for benzidine and ortho-tolidin. (Translator.)

weak solution keeps at least 3 months. As Cl decolorizes methyl red, I add per 100 cm.^{3} of the diluted solution 5 cm.^{3} N/100 $Na_2S_2O_3$. In the alkaline solution the thiosulphate keeps well; as a matter of fact, we are dealing with such extremely small quantities of Cl that the thiosulphate can very well be dispensed with without fear of reduced depth of color in the methyl red.[7]

The determination of free chlorine is carried out in the following manner:

Into each of two glass cylinders is poured 100 cm.^{3} of the water to be tested. These are acidified with 2 cm.^{3} N/10 HCl (our tap water has an alkalinity corresponding to from 2 to 7 cm.^{3} N/10 per liter). To the one sample is added 1 cm.^{3} of the indicator which is then allowed to stand two minutes; to the other sample is added methyl red solution from a little burette, until the standard has the same color as the sample. By the use of 100 cm.^{3} water one can determine 0.01 mgm. per liter and upwards. If the Cl content exceeds 0.15 to 0.2, 50 cm.^{3} water is used instead of 100 cm.^{3}.

For our tap water I now use a 0.4 per cent solution of dimethyl-p-phenylenediaminechlorinehydrate which per 100 cm.^{3} contains 8 cm.^{3} concentrated hydrochloric acid. Of this solution 0.25 cm.^{3} is used per 100 cm.^{3} water, or 6 drops from a dropping bottle. The solution keeps a long time.

Kolthoff states that 0.03 mgm. per liter Cl can be determined with this indicator, while I, as described, determine 0.01 mgm. per liter. On what this difference in result depends, it is difficult to say, but I rather think that Kolthoff used more acid solution than I.

TRANSLATORS NOTE: Since the above was written the Author in a letter to the Translator says:

Both ortho-tolidin and dimethyl-p-phenylenediaminechlorinehydrate as indicators for Cl have their advantages and disadvantages.

To the credit of ortho-tolidin I would put its independence of pH in acid solution and its insensitiveness to reasonable amounts of iron. Its disadvantages in my opinion are that the color of reaction is yellow and that for colorimetric analysis one requires a mixture of two solutions ($CuSO_4$ and $K_2Cr_2O_7$)[8] varying in proportion for different amounts of Cl. The latter disadvantage, however, is considerably reduced by the use of La Motte's Enslow Comparator, assuming that the standards retain their color and intensity for an indefinite time.

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[7] Of course, distilled water can be used, but by using the same water as that under test any effect due to its color (if any) will be the same in both sample and standard. (Translator.)

[8] See A.P.H.A. Standard Methods. (Translator.)

The disadvantages with dimethyl-p-phenylenediaminechlorinehydrate are firstly its sensitiveness to iron greater than 0.1 mgm. per liter $Fe^{\cdot\cdot\cdot}$, and secondly that the pH of the sample must be between 2.6 and 3.4. It is, however an easy matter to keep the pH value within this relatively large range.

A really great advantage in my opinion is the particularly beautiful and, even with small amounts of Cl, the distinct red color of the reaction. Another advantage is, as you pointed out, that only one solution—methyl red—is required for color comparison. A further advantage is that only two minutes are required for reaction and the color to reach its full depth.

I have now used the method for nearly a year and am satisfied with it.

REPORT OF THE SECRETARY FOR THE YEAR 1926

STATEMENT OF INCOME AND EXPENDITURE

Income:		
Initiation Fees	$1,829.91	
Annual Dues	18,736.31	
Advertising	13,358.64	
Subscriptions to JOURNAL	1,410.01	
Sales of JOURNALS, unbound	199.25	
Sales of JOURNALS, bound	162.50	
Sales of Hydrant and Valve Specifications	4.50	
Sales of Manuals	1,124.50	
Royalties on Manuals	1,152.00	
Interest on Deposits	84.48	
Interest on Investments	736.00	
Sundry	12.13	$38,810.23
Expenditure:		
Convention Expense	$1,397.37	
Office Expense	1,608.63	
Committee Expense	2,240.09	
Section and Division Expense	1,746.53	
Insurance	47.00	
Office of Secretary	10,119.94	
Salary of Editor	2,000.00	
Printing JOURNAL	18,943.17	
Contingencies	88.76	
Rent of Office	1,200.00	
Exchange on Checks	13.65	
Diven Memorial Medal	762.10	
Manuals, Purchases	870.00	
Manuals, Publication Cost (Balance)	1,271.87	
Provision for Depreciation of Office Furniture	77.51	
Investments (loss on sale)	31.56	42,418.18
Loss in Year's Operation		$3,607.95

MEMBERSHIP STATEMENT FOR THE YEAR 1926

	ACTIVE	CORPORATE	ASSOCIATE	HONORARY	TOTAL
January 1, 1926	1,841	174	189	12	2,216
New during 1926	264	29	36		329
Restored in 1926	22		1		23
Transferred—Active to Honorary				4	4
	2,127	203	226	16	2,572
Losses:					
Resignations	45	4	11		60
	2,082	199	215	16	2,512
Deaths	15			1	16
	2,067	199	215	15	2,496
Transferred—Active to Honorary	4				4
	2,063	199	215	15	2,492
Dropped for non-payment of dues 12/31/26	83	4	2		89
Total December 31, 1926	1,980	195	213	15	2,403
Total January 1, 1926	1,841	174	189	12	2,216
Gain in 1926	139	21	24	3	187

REPORT OF THE SECRETARY FOR THE YEAR 1927

STATEMENT OF INCOME AND EXPENDITURE

Income:		
Initiation Fees	$1,589.55	
Annual Dues	27,424.59	
Advertising	17,528.26	
Subscriptions to JOURNAL	1,713.98	
Sales of JOURNALS	183.50	
Sales of Pipe Specifications	42.44	
Sales of Meter Specifications	35.40	
Sales of Manuals	545.00	
Royalties on Manual Sales (6/30/27)	373.50	
Interest on Deposits	122.47	
Interest on Investments	677.62	
Sundry	68.48	$50,304.79
Expenditure:		
Convention Expense	$1,680.37	
Office Expense	1,949.37	
Committee Expense	2,399.84	
Section and Division Expense	2,507.76	
Insurance	52.00	
Office of Secretary	13,032.49	
Salary of Editor	2,000.00	
Editor's Assistants	611.50	
Printing JOURNAL	19,795.62*	
Contingencies	192.64	
Rent of Office	2,100.00	
Exchange on Checks	2.19	
Depreciation, Office Equipment	139.81	
Reprints	287.15	
Manuals, Purchases	386.25	
Adjustment of Manual Sales (1926)	125.00	47,261.99
Income over Expenditure, year ending 12/31/27		$3,042.80

* Includes cost of printing 1927 Membership List, $950.00.

MEMBERSHIP STATEMENT FOR THE YEAR 1927

	ACTIVE	CORPORATE	ASSOCIATE	HONORARY	TOTAL
January 1, 1927	1,980	195	213	15	2,403
Gains:					
New	235	17	32		284
Restored	23	1	1		25
	2,238	213	246	15	2,712
Losses:					
Resignations	93	11	15		119
	2,145	202	231	15	2,593
Deaths	26			1	27
	2,119	202	231	14	2,566
Dropped for non-payment of dues 12/31/27	111	3	10		124
Total December 31, 1927	2,008	199	221	14	2,442
Total January 1, 1927	1,980	195	213	15	2,403
Gain or Loss in year 1927	28	4	8	−1	39

DISCUSSION

THE HYDRAULICS OF FILTER UNDERDRAINS

In his article "Design of perforated pipe strainer system"[1] J. W. Ellms communicates the results of his experiments on the checking of the rules for designing drainage systems determined in 1920 at Sacramento, California, by H. N. Jenks.

Ellms states:

> The experiments at Sacramento were confined to the relation between the perforations and the laterals and showed that it was possible to obtain a fairly uniform discharge from the perforations, if there was a proper ratio between the sum of the cross sectional areas of the perforations and the cross sectional area of the lateral. It seemed to the writer, that to make this investigation complete it was desirable to go one step further and determine the proper relation between the sum of the cross sectional areas of the laterals and the cross sectional area of the header or manifold (page 665).

By his experiments, Ellms tries to state the perfectly correct idea, that it is possible for large filters to use only one main header placed in the center with laterals extending one half of the filter width, while the present practice requires two rows of main headers, the laterals extending only one quarter of the filter wideth.

In Ellms' experiment a 10 inch header and $3\frac{1}{2}$ inch laterals, 16 feet long were used. Figure 1, page 666, shows the whole plant. The experiments were conducted with various quantities of working laterals—from 4 to 14 units. The spacing of the laterals on centers was $9\frac{1}{16}$ inches; the perforations were $\frac{3}{64}$ inch in diameter and were spaced on $7\frac{3}{4}$ inch centers. The filter area corresponding to all the 15 laterals would be 172.4 square feet, viz. 16.016 square meters, or for one lateral 1.065 square meters. Figure 4 computed for 8 working laterals shows that the velocity head is converted in all laterals. In the 10 inch header the head at the initial point "H" for the different rates of washing employed from 500 to 750 mm. is always, except one case figure 2, lower than at the final point "D," as well as in the

[1] Journal, December, 1927, page 664.

laterals, the head invariably increases to the end. But correct data on the phenomenon of the conversion of velocity head regretfully are not to be received. Two circumstances prevent it: the water to the 10 inch header is led at 90°, therefore at the beginning of the laterals the phenomenon is distorted by eddies inevitable at such a sharp turn; at the small number of laterals, 4 to 6, the conversion of velocity head is prevented by the loss on eddies, which appear owing to the rapid fall of velocity to zero in the 10 inch header. The velocity head is converted almost completely at a gradually decreasing velocity, which phenomenon occurs at a large number of laterals on a certain length of the pipe. In figure 2 on page 669 for 4 working laterals the head at point "D" always remains lower than the head at point "H", i.e. there is no conversion of head in the 10 inch header, but, on the contrary, a considerable loss of head is to be noticed. This loss of head is caused by the eddies at rapidly decreasing velocities, somewhat less in this phenomenon noticeable at 6 laterals.

The head at "H" (fig. 1) in all diagrams is influenced by the sharp turning at 90° of the inlet flow, eddies decrease the head at turning point, so that Ellms' diagrams do not represent an accurate picture of heads in a correctly constructed drainage system.

To characterize the phenomenon Ellms uses 4 relations between the area of perforations and the cross section of lateral, the sum of cross sections of laterals and the cross section of main header, etc.

My opinion is that all these relations were valuable, only we did not know accurately how the pressure was distributed on the length of the perforation. At present the design of a drainage system may be made in a more simple and accurate way. If we know the velocities at the given diameters of the main header (v_1) and the laterals (v_2) we find the sum of converted heads $\frac{v_1^2}{2g} + \frac{v_2^2}{2g}$ which will somewhat exceed (15 per cent) the maximum difference of heads in the drainage system. If the head at the beginning of the header is "H," then the relation $\sqrt{H + \frac{v_1^2}{2g} + \frac{v_2^2}{2g}} : \sqrt{H}$ gives us the relation of the maximum volume to the minimum volume of water flowing through the perforations.

Now, on the ground of the experiments with the present filters, it remains to determine what difference in the water-flow through the extreme perforations is allowable without damage for washing. It appears that a difference not exceeding 8 per cent is to be allowed.

In Cleveland's filters the velocity at the beginning of the $2\frac{1}{2}$ inch lateral is about 1 meter, therefore, $\frac{v_2^2}{2g} = \frac{1}{2.981} = 0.050$ meter. Velocity at the beginning of the main header is approximately 1.15 meter. $\frac{v_1^2}{2g} = 0.057$. In this way the maximum difference of the heads is 0.117 meter. How the converted head should be distributed between the main header and the laterals is a matter of free choice. There is a possibility of such a case as at Cleveland where they are almost equal.

If the laterals must be longer, then on decreasing the converted head, i.e., increasing the cross section of the main header you may allow a greater converted head in the laterals, i.e., a greater velocity in them. For large filters there is no necessity in making the usual complex combination with two supply pipes on 8 main headers as, for example, in Baltimore filters.

The volume of water required for washing these filters of an area of 169 square meters is 1.69 cubic meters per second. At the header diameter = 1.20 m., $v_1 = 1.50$ meter, $\frac{v_1^2}{2g} = 0.115$ meter.

In the $3\frac{1}{2}$ inch lateral, 16 feet long, corresponding to an area of 1.065 square meters the volume of water is 10.65 liters per second, $v_2 = 1.69$ meter, $\frac{v_2^2}{2g} = 0.146$. So the degree of the variation of the head at washing at the rate of 60 cm. per minute will be less than $0.115 + 0.146 = 0.261$ m.

Assuming the initial head, 2.12 meters, according to the preceding formula, we obtain the relation of the maximum to the minimum volume less than $\sqrt{2.38} : \sqrt{2.12} = 1.057$.

The diameter of the main header is large—1.20 meter. Probably the diameter of the drainage pipes may be decreased, but to counteract the converted velocity head there should be inserted in the pipe artificial resistances. By inserting artificial resistances in the pipes, it is probably possible to attain the complete exhaustion of the velocity head and to attain a more perfect uniformity of distribution. The author had no possibility to make experiments promised in his preceding article.[2]

N. Malishewsky.[3]

[2] Journal, June, 1927, page 667.

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EDITORIAL COMMENT

Force Account on Construction Contracts

The effort to unify various features of construction contracts and specifications has resulted in the last five years in the development of standardized principles and language helpful to owners, engineers and contractors for engineering structures. Wide differences in contract specifications, however, still persist, even though attempts at evaluating relative advantages and disadvantages are still in process.

A contribution toward the advance in specification writing and in summarizing the wide variations which still exist in a single, although important, detail is made by the issuance of a report by the Bureau of Municipal Research of Philadelphia, on "Force Accounts on Unit Price Construction Contracts." This report was written under date of April 4, 1928 and represents an effort on the part of the Bureau to analyze the practices in specification writing when dealing with force accounts on unit price contracts. The most striking finding in the report is the great diversity in existing specifications governing municipal public works. All of the findings, however, point to the desirability of greater uniformity in specifications for the future. None of the observed contrasts make such unifying impossible.

The report is particularly interesting in that it reviews the practices of some 22 municipalities in the United States. It summarizes the method of paying for "extra work" by the following plans:

1. At the unit prices bid by the contractor.
2. At fixed prices stated in the specifications.
3. Under a special unit-price agreement between the contracting parties.
4. With a lump sum, agreed upon between the engineer and the contractor.
5. By force account, on a cost-plus-a-percentage basis.
6. At cost plus a fixed sum.

The disabilities or advantages of each of the above procedures are analyzed and the conclusion is reached that the "force account method is frequently the only practicable one." The force account procedure is recognized as susceptible to much abuse. The inexperienced engineer, in order to avoid detailing to the maximum the num-

ber of unit items in the contract, may sometimes take the easier method of using force account for work easily subject to prior classification and appraisal. If the force account basis is used on a large percentage of the total work, the contractor has the inducement of expanding the volume of work in order to reach more attractive profits. The discussion of force account practices is presented in detail under the following general headings:

Fixing the percentage in the specifications
Items on which percentage is allowed
What the percentage pays for
How much should the percentage be?
Rental of plant and equipment
Repairs to plant
Reservation of right to furnish materials
Making force-account work part of the contract
Limiting the amount of force-account work
Written order required
Written agreement on costs
Daily time sheets
Monthly bills and payments
Extension of time

The peculiar practice of fixing the percentage in the specifications and having the contractor bid the percentage has been used on a number of contracts in the City of Philadelphia. Under this scheme an estimated amount of force account work is named in the specifications. The contractor bids a percentage to be added to the estimate on the total work, which results in a figure giving a total for the unit price work and the extra work. This total is used in comparison with other bids arranged on the same principle in order to decide which was lowest. The extreme danger of this practice is illustrated in the two contracts let in 1916 for subway work under City Hall and Penn Square. It was agreed that this work would be done for $1,978,000, of which $78,000 was estimated for force account. As it turned out, the force account, due to extensive underpinning beneath the City Hall, was over $1,000,000. The force account, which, in this instance, was less than 4 per cent of the combined contract prices, actually amounted to 36 per cent of the total paid under the contracts. The plan is pernicious in either direction in that it enables the contractor, if specially familiar with local conditions, to bid a high percentage on force account and a low unit price on the other items. The total bid is kept down, but the anticipated increased expenditure for force account may lead to undue profits.

In the items on which percentage is allowed in extra work, variations occur in practically all the specifications examined. Here too, no effort has been made to standardize, although there is obvious advantage in so doing. In the 30 specifications of other cities studied, cost plus a percentage is paid on labor, 26 pay cost plus a percentage on materials, 4 pay cost only.

On plant rental, 6 pay a percentage, 12 pay rental without a percentage, while 6 pay no rental, but include plant costs in the percentage. Six of the specifications make no comment on rental.

A percentage is paid on the cost of insurance on labor by 7. Eleven pay insurance cost only. In 8, the insurance is included in the percentage, while 4 do not refer to insurance.

In the determination of "actual cost," the report makes mention of the suggestion by Allen, in "Business Law for Engineers," pages 16 to 60, that "Reasonable direct cost is preferable to actual cost, since the actual cost to the contractor may be twice what it ought to be if the contractor buys material from a friend and the city pays for it."

The discussion on what the percentage pays for is particularly interesting in view again of the wide disparity between the specifications of the various municipalities. Even a cursory review of arbitration proceedings on force account work indicates the necessity and desirability of unifying specifications in such a fashion as to make clear exactly what the percentage is intended to cover. The report goes on record that the specifications should allow workmen's compensation insurance as an item of cost chargeable to the city. It leaves open the question as to whether a percentage should be superimposed on this cost.

The detailed analyses should be of interest to most readers engaged in any type of municipal or private contract work. A general summary of the conclusions and recommendations of the Bureau of Municipal Research is presented in abstract herewith.

1. The specifications should be truly specific and should be standardized as far as practicable. Every point which, so far as can be forseen, may raise a question between the contractor and the engineer during performance of the contract, or in the mind of the contractor at the time of making his proposal, should be covered in the specifications. As has been shown, Philadelphia specifications concerning force account leave important questions uncovered. Standardization of specifications—that is, uniformity with other cities—is, of course,

not a matter solely within the city's control. However, Philadelphia officials should take advantage of every opportunity to promote uniform specifications. Completeness and uniformity of specifications should encourage bidding, especially by out-of-town contractors, by reducing the necessity of guarding against surprises which may otherwise be encountered during the course of the work.

2. Extra work probably cannot be avoided on major construction, and provision should be made for it in the specifications.

3. A schedule of fixed prices for extra work is of doubtful utility for the reason that if the kind, quantity, and cost of the work (all of which must be known in order to fix prices intelligently) can be foreseen, it would be better to provide for the extra work in the schedule of items and unit prices; and if they cannot be foreseen, any figures prepared by the engineers must be guesswork, which is contrary to the whole theory and intent of the specifications.

4. It would seem best to use force account only where other methods of paying for extra work are impracticable. Other methods should, therefore, be provided for in the specifications; but force account should also be provided for in the event that the other methods are found impracticable.

5. The percentage to be allowed on force-account work should be fixed at a reasonable rate stated in the specifications.

6. The items on which the percentage is allowed and the items for which the percentage is meant to compensate the contractor should be stated in the specifications.

7. The specifications should provide for the rental of plant, equipment, and power tools at prices to be agreed upon in writing, and should state how plant repairs are to be taken care of. No percentage should be allowed on rental.

8. Extra work should be expressly made a part of the contract, subject to all the conditions of it, especially those referring to insurance, and the fixing of responsibility for accident.

9. On large contracts the amount which can be spent on extra work should be limited to some percentage of the contract price and a sum should be set beyond which payment for extra work cannot be made without additional authorization.

10. It may be desirable at times for the city to furnish materials for construction. The specifications should therefore reserve this right. On the question whether the contractor should be allowed a percentage on the cost of materials furnished by the city no recommendation is made.

11. Except for work done in emergencies, claims for force-account work should not be valid unless based on written orders, and costs should be agreed upon in writing before work is begun.

12. Specifications should provide for daily checking of time sheets by representatives of the contractor and the engineer and for the filing of the sheets in their respective offices.

13. Payments for extra work should be made monthly and should be based on monthly statements made by the contractor.

14. Specifications should give the contractor the right to an extension of time for the completion of a contract delayed by the necessity of doing extra work.

ABEL WOLMAN.[1]

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ABSTRACTS OF WATER WORKS LITERATURE[1]

Frank Hannan

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Biennial Report of the Division of Water Rights, Calif. Dept. Public Works, for the Period September 1, 1924 to September 1, 1926. Edward Hyatt, Jr., Chief, 157 pp., 1927. Report of activities of Division of Water Rights in the supervision of appropriation of water, adjudication of existing water rights, administrative distribution of water, and special investigations. Brief notes on progress in special investigations of ground water in southern San Joaquin Valley, storage of surface water for irrigation and flood control, and recharge of ground water reservoir in San Gabriel River basin, quantity of water returning from irrigation to Sacramento and San Joaquin Rivers, encroachment of salt water in lower part of Sacramento and San Joaquin Rivers during periods of low flow, and other special studies.—*David G. Thompson.*

Water Supplies and Sewerage Systems for Municipalities. Minnesota State Board of Health, Division of Sanitation, 39 pp., July, 1927. Gives requirements to be observed in design of water supply and sewerage systems. Twenty-two illustrations, showing right and wrong ways to construct dug and drilled wells, install pumps, finish reservoirs, etc., so they will be protected from pollution, make this a valuable pamphlet.—*David G. Thompson.*

Biennial Report of State Engineer of Nevada for 1925–1926. Robert A. Allen. Contains brief notes on adjudication of water rights and distribution of water during dry seasons according to existing rights. Brief statement by J. E. Church, Jr., describes work of snow surveys in estimating stream discharge.—*David G. Thompson.*

Large Springs in the United States. O. E. Meinzer. U. S. Geological Survey Water Supply Paper **557**: 94 pp., illus., 1927. Gives classification of springs according to magnitude. Describes nearly 200 large springs in United States, mostly of first magnitude, that is, springs that have a discharge of 100 second-feet or more. Several springs or groups of springs have an average

[1] Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

discharge of 500 second-feet or more. Largest spring in United States probably is Silver Spring which issues from limestone in Florida and has measured discharges ranging from 342 to 822 second feet, the latter quantity equal to average daily consumption in New York City in 1916. Springs issuing from volcanic rocks in a 40-mile stretch along Snake River in Idaho discharge more than 5,000 second feet of water. Many springs yield enough water to supply cities as large as Washington, D. C. Springs of first magnitude found only in a few states and occur mainly in limestone, which contains large solution channels, or in volcanic rocks which are much jointed. Hydrographs show relations between fluctuations in discharge and precipitation.—*David G. Thompson.*

Plants as Indicators of Ground Water. O. E. Meinzer. U. S. Geological Survey Water Supply Paper **577**: 95 pp., 27 illus., 1927. Describes relation of certain plants, termed "phreatophytes" to ground water, especially in arid regions. These plants give some indication as to the presence of ground water, depth to it, and its quality. They also furnish some clues to quantity of ground water discharged by evaporation and transpiration in areas where water is near the surface, an important factor in determining available supplies for irrigation.—*David G. Thompson.*

Quality of Water of Pecos River in Texas. W. D. Collins and H. B. Riffenburg. U. S. Geological Survey Water Supply Paper **596**: pp. 67–88, 1927. Gives results of 235 analyses of water from Pecos River at several points in New Mexico and Texas at intervals during period 1922 to 1925; discusses changes in quality from place to place; and by means of graphs shows relations between fluctuations in discharge of river and dissolved mineral matter.—*David G. Thompson.*

A Comparison of Ground Temperatures at Different Depths and Temperature Fluctuations of the Atmosphere. E. L. Rawlins and T. W. Johnson. U. S. Bur. Mines Reports of Investigations **2857**: February 1928. 3 mimeographed pages and 2 diagrams. Describes tests at Bartlesville, Okla., to determine relations between fluctuations of atmospheric temperature and soil temperature at depths of 1 to 4 feet to serve as basis for estimating depths at which pipe lines should be buried.—*David G. Thompson.*

Report of Honolulu Sewer and Water Commission for Period Ending December 31, 1926. 65 pp., 1927. Contains technical reports on investigations of water and sewerage. City of Honolulu is almost wholly dependent upon wells for water supply. Consumption of ground water about 52 m.g.d. but safe yield of artesians basins estimated at only 42 m.g.d. Overdraft has caused considerable lowering of head with resulting contamination of deeper wells by salt water. It is believed that if present overdraft is not eliminated soon the danger from salt water will not only become critical between 1931 and 1935, but it may become a menace to the economic welfare of the island on which the city is located. The Commission recommends legislation authorizing complete government ownership and control of artesian waters in District of

Honolulu, including power to condemn all wells, to prohibit drilling of new wells except for government use, to seal all wells not needed for public purposes, and to prohibit use of artesian water in wet land irrigation within the district.—*David G. Thompson.*

The Geology of the Honolulu Artesian System. HAROLD S. PALMER. Supplement to report of Honolulu Sewer and Water Commission, 68 pp., 1927. Describes geology and hydrology of artesian system which is principal source of water for City of Honolulu. Water occurs in very porous lavas which are overlain by more or less impervious beds of ash, clay, coral, sand, and gravel. Water-bearing beds outcrop on ocean bottom at estimated depth of about 1500 feet. Artesian pressure created largely by greater specific gravity of ocean water which for depth just given caused fresh water in aquifer to stand originally 35 to 42 feet above sea level. Overdraft on artesian reservoir has caused gradual lowering of fresh water head to 18 to 24 feet above sea level. According to theory of HERZBERG a decline of 1 foot in the fresh water head allows the salt water to rise about 40 feet, so that the decline in artesian head stated above shows that the contact zone between fresh and salt water has risen several hundred feet, and deeper wells have become contaminated. The chloride content in a 540 foot well was reduced from 730 parts per million to 125 parts by plugging the lower 82 feet of the hole.—*David G. Thompson.*

Laboratory Tests on Physical Properties of Water Bearing Materials. NORAH D. STEARNS. U. S. Geol. Survey Water Supply Paper **596**: pp. 121–176, 1927. Describes methods employed and gives results of tests of apparent specific gravity, mechanical composition, porosity, moisture equivalent (or specific retention), and coefficient of permeability of 97 samples of unconsolidated water-bearing material (sand, gravel, and clay) from New Jersey, Montana, and Idaho. Also gives computed results for uniformity coefficient, 10 per cent size (often called effective size) and porosity minus moisture equivalent or specific yield. Coefficient of permeability is defined as rate of flow, in gallons a day, passing through a square foot of cross section of material, under a hydraulic gradient of 100 per cent at a temperature of 60°F. Permeability tests were made with difference in head equivalent to hydraulic gradients ranging from about 35 feet to 4,800 feet per mile and special tests on one sand were made with a gradient as low as 1 foot per mile. All tests seem to indicate that DARCY's law for flow of water through soils is probably reliable even in fine sands for gradients only of 5 feet per mile or less. Work of HAZEN, KING, and SLICHTER on effective size in relation to permeability, especially different uses of term "effective size," is discussed.—*David G. Thompson.*

Report of the Duty of Water Committee of the Irrigation Division on the Consumptive Use of Water in Irrigation. Proc. Am. Soc. Civ. Eng., **54**: 4, 214–42, April, 1928. The committee proposes detailed definitions of the consumptive use of water in irrigation, and calls attention to differences between the basic meaning of consumptive use and its application to the farm, the project, and the valley. Difficulties in making a dependable determination of consumptive use are enumerated and discussed. Investigations con-

cerning the consumptive use of water in typical irrigated valleys of the West are reported.—*John R. Baylis.*

Progress Report of the Committee of the Sanitary Engineering Division on Filtering Materials for Water and Sewage Works. Proc. Am. Soc. Civ. Eng., **54**: 4, 243–80, April, 1928. The committee is studying the methods of testing and selecting filter materials for water and sewage works. Replies to an inquiry sent to the State Sanitary Engineers with reference to depth and size of sand for water filters indicate that there is no close agreement as to the proper sand. A number of cities throughout the country have been asked to coöperate with the committee in conducting a series of experiments, using a battery of small glass filters, which should be operated in conjunction with one of the large filter units of the plant where the experiment is to be conducted. Methods used in the past for selecting filtering materials for sewage trickling filters suggested tentative methods of sampling such materials and tests to determine their suitability are discussed. The committee outlines a proposed procedure for conducting tests on filtering materials, and describes and illustrates the equipment to be used in conducting the tests.—*John R. Baylis.*

Hydrostatic Uplift in Pervious Soils. H. de B. Parsons. Proc. Am. Soc. Civ. Eng., **54**: 4, 941–56, April, 1928. Tests were made to determine the hydrostatic uplift on the base of a structure located on pervious soil. The area on which the uplift acts is approximately 90 to 100 per cent of the total area.—*John R. Baylis.*

Flood Control on the River Po in Italy. John R. Freeman. Proc. Am. Soc. Civ. Eng., **54**: 4, 957–92, April, 1928. There has been an increase in the elevation to which great floods have risen. This is probably due to confining the waters within narrower limits and to the building up of deposits of sediment on the land between the main dikes and the river. The River Po presents many problems similar to those of the Mississippi.—*John R. Baylis.*

Load Distribution in High Arch Dams. R. A. Sutherland. Proc. Am. Soc. Civ. Eng., **54**: 4, 1027–1069, April, 1928. Methods of design generally adopted do not make full use of the strength of the materials involved. The principles and methods by which a knowledge may be obtained of the various forces acting on the dam are discussed. Previous methods of load analysis have been based on assumptions which aimed at reducing the complexity of factors involved. The principal assumptions are reviewed, and the one most strongly attacked is that which regards the arch as being uniformly loaded. The methods of load analysis proposed are based on beam and arch deflections, the application of which is made comparatively simple by the aid of charts. Eighty-eight equations and a number of charts are given in the paper.—*John R. Baylis.*

Evaluation of Water Rights. J. E. Field. Proc. Am. Soc. Civ. Eng., **54**: 4, 1071–8, April, 1928. The market value of an acre-foot of water in a given

locality does not vary whether its use be domestic, manufacturing, or agricultural. Stored water has little more value than unstored water providing the use of the unstored water is economical and beneficial. The value of water for domestic purposes should not be based on the city's necessities, but on the value of water for agricultural purposes.—*John R. Baylis.*

Administrative Water Problems. A Symposium. Proc. Am. Soc. Civ. Eng., **54**: 4, 1079–96, April, 1928. **Transmission and Delivery of Reservoir Water.** G. C. Baldwin. The author discusses difficulties encountered in the transmission and equitable distribution of irrigation water. **Administration of Stream Flow.** E. Hyatt. The conflict between the opposing legal principles of riparian and appropriative water rights has retarded water development in California. **Present Tendencies in Water Administration.** G. M. Bacon. The discussion is confined to practice and experience in Utah. The State Engineer has authority to establish water districts and appoint water commissioners to distribute the water. The success of the administration of water rights is dependent wholly on exact descriptions and definitions of such rights. All the water sources in Utah are heavily over-appropriated, which means that the problem of distribution is entirely different in a dry year from that in a wet year. Assessments should be on water rights with such adjustment as will make them agree approximately with the value of the right in terms of available supply.—*John R. Baylis.*

Return Water and Drainage Recovery from Irrigation. A Symposium. Proc. Am. Soc. Civ. Eng., **54**: 4, 1097–107, April, 1928. **Return Water, North Platte River, Nebraska.** R. H. Willis. Approximately 1,200,000 acre-feet have been diverted from the stream during each of the seasons of 1925, 1926, and 1927, between Whalen, Wyo., and Bridgeport, Nebr. About 65 per cent of this water came back to the stream as "return water," "return flow," "seepage," and "unused water." **Drainage Recovery from Irrigation.** D. W. Murphy. Part of the water applied in irrigation sinks below the zone of plant growth and is wasted. The quantity that can be recovered by drainage depends largely on the character of the underground formation. It may vary from nothing to possibly as high as 20 to 25 per cent of the applied water.—*John R. Baylis.*

Trans-Mountain Diversions. A Symposium. Proc. Am. Soc. Civ. Eng., **54**: 4, 1109–31, April, 1928. **Inter-Water-Shed Diversions by Tunnels on United States Reclamation Projects.** E. B. Debler. The author gives a brief description of the construction of the Gunnison and Strawberry tunnels in Colorado and Utah for diverting waters from one watershed to another for irrigation purposes. **The Proposed Los Angeles-Colorado River Aqueduct.** H. A. van Norman. The paper discusses the need, in Southern California cities, for water from the Colorado River. At the present rate of growth of Los Angeles the present water supply will have reached its maximum capacity within 10 years. There are several possible routes, two of which are gigantic pumping schemes and two others, gravity routes having tunnels of unusual lengths. The Blythe Route would require the water to be elevated 1,400 feet,

the lifting to be done in five stages. The Black Canyon Route would require the water to be lifted even higher. One of the suggested gravity routes would be 370 miles in length, 170 miles of which would be tunnels. One tunnel would be 80 miles in length and another 71 miles. Another suggested gravity route would be more than 750 miles in length. **Trans-Mountain Diversion in Colorado.** R. FOLLANSBEE. With the present supply the limit of irrigation on the plains in Colorado has almost been reached. Water from the mountainous region is being diverted to the head-waters of the streams on the eastern slope.—*John R. Baylis.*

Precise Weir Measurements. E. W. SCHODER and K. B. TURNER. **Discussion.** Proc. Am. Soc. Civ. Eng., **54:** 4, 1157–63, April, 1928. W. S. PARDOE. Coefficient curves of experiments made in the Hydraulic Laboratory of the Civil Engineering Department of the University of Pennsylvania are given. For heads from 0.2 to 0.8 ft. the Francis formula seems quite accurate.—*John R. Baylis.*

Historic Review of the Development of Sanitary Engineering in the United States During the Past One Hundred and Fifty Years. A Symposium. Discussion. Proc. Am. Soc. Civ. Eng., **54:** 4, 1171–6. H. G. PAYROW. Discusses briefly the first water works pumping plant at Bethlehem, Pa. Plan of the distribution system is given. The pipes were generally bored hemlock logs. G. W. FULLER. H. P. EDDY. G. T. PALMER. Brief comments on the discussions of their papers are made by Messrs. FULLER, EDDY and PALMER. *John R. Baylis.*

New Theory for the Centrifugal Pump. A. F. SHERZER. **Discussion.** Proc. Am. Soc. Civ. Eng., **54:** 4, 1177–93, April, 1928. M. MEDICI. Criticism of the fallacies of modern theories of centrifugal pumps is well founded only as applied to theories that are typical of British and American texts. The author does not concur in the opinion of Prof. SHERZER as to the effect of the vane angle on the shape of the pump characteristics. The author reached the same conclusions as did Prof. SHERZER in regards to the effect of the casings on series pumps. An abridgement of his paper on "The Theoretical Potentiality of Centrifugal Impellers" is given. It contains a number of equations and several illustrations. A. H. BLAISDELL. The author does not agree with Prof. SHERZER in regards to the force producing the water head. M. P. O'BRIEN. Discusses several points very briefly.—*John R. Baylis.*

Making Joint in Water Tank Where Steel Shell Joins Concrete Base. I. E. FLAA. Eng. News-Rec., **100:** 394, March 8, 1928. Regulating tank of 300,000 gallons capacity, constructed recently in extending distribution system of Spring Valley Water Co. of San Francisco, was designed as circular steel wall mounted on concrete base. Design was such that cylindrical shell is free to move, within certain limits, on concrete base, reasons being that: (1) it would lessen damage of rupture in lower seams in event of an earthquake; (2) it would provide for expansion and contraction when tank is empty; and (3) it should increase life of structure as compared with all-steel-tank, as steel

tank bottoms deteriorate more rapidly than shells. Concrete base is 12 inches, and outer 3 feet about 18 inches in thickness. Watertight joint between shell and base was obtained by forming depression in concrete at time of pouring, in which was embedded an 8 by 6 by $\frac{7}{16}$-inch angle set so it would be immediately beneath shell. On this foundation was placed a 5 by 5 by $\frac{5}{8}$-inch angle riveted to bottom of steel plate in first ring of superstructure. After shell was erected, the inside of the depression in concrete was first calked with oakum and then filled with asphalt filler. Outside of depression was also filled with same material. Full load test, which imposed pressure of about 11 pounds per square inch on joint, showed it to be absolutely watertight.—*R. E. Thompson.*

Unusual Tank and Tower Structure of Reinforced Concrete. Eng. News-Rec. **100:** 247, February 9, 1928. Brief illustrated description of elevated tank which has been in service 10 years at Patea, New Zealand, during which time it has successfully withstood several earthquakes and a number of severe gales. As it was situated near sea coast and subject to high winds carrying salt spray it was constructed of reinforced concrete, with tower height of 120 feet, panels being 30 feet. Capacity is 75,000 Imperial gallons, and tank shell is 15 feet high.—*R. E. Thompson.*

Rules for Heating Elevated Water Tanks. Eng. News-Rec., **100:** 244, February 9, 1928. Rules of National Board of Fire Underwriters for heating water in elevated tanks to prevent freezing outlined. Circulation of hot water is recommended, steam coils being considered unsuitable except where intermittent heating can be employed. Table is included showing heat loss from steel and wooden tanks of 25,000 to 100,000 gallons capacity at atmospheric temperatures of 0° to 60°F.—*R. E. Thompson.*

Water Works Reconstruction in Winter at Newton, N. J. HARRY G. PAYROW. Eng. News-Rec., **100:** 184–5, February 2, 1928. Illustrated description of construction of new intake works in Morris Lake, source of supply of Newton, N. J. After lake was acquired in 1895, a stone masonry dam was built to height of 30 feet, replacing small earth dam. A 12-inch cast iron pipe conveyed the water from steel intake standpipe through dam to point 1200 feet downstream, where it was reduced to 10-inch pipe leading to the town, 9 miles from lake. During winter of 1926–27, with surface of lake frozen, submerged concrete intake covered with conical brass screen was placed in 35 feet of water and about 600 feet of 20-inch reinforced concrete pipe laid connecting intake with new gate house constructed at dam. To repair dam, which was seeping water at certain points, upstream face was dewatered by means of wooden cofferdam. Upper portion of dam was demolished and replaced with concrete, increasing height 3 feet, and reinforced-concrete facing, 1 to 2 feet in thickness, was placed on upstream face.—*R. E. Thompson.*

Maintenance of Flood Control Works of Miami District. C. S. BENNETT. Eng. News-Rec., **100:** 186–8, February 2, 1928. Illustrated description of maintenance and improvement work being carried on by Miami Conservancy

District in connection with flood control works in southwestern Ohio which have been in operation about 5 years.—*R. E. Thompson.*

Los Angeles Flood Control. Eng. News-Rec., **100**: 81, January 12, 1928. Data on status of various dams included in program. Pacoima dam, an arched structure that will have record height of 365 feet above stream bed will be completed by May, 1928.—*R. E. Thompson.*

Colorado River Aqueduct. Eng. News-Rec., **100**: 81, January 12, 1928. Field studies were completed in 1927 which have been under way 4 years, covering 18,000 square miles of desert country that will be traversed by proposed aqueduct from Colorado River to Los Angeles, a distance of 260 miles. Cost estimates are being prepared.—*R. E. Thompson.*

New Cascade Railroad Tunnel. Eng. News-Rec., **100**: 81, January 12, 1928. Progress on 7.77-mile tunnel being driven for Great Northern Railway in Cascade Mountains, Wash., outlined.—*R. E. Thompson.*

Wall Castings for Cast Iron Pipe. THOMAS F. WOLFE. Eng. News-Rec., **100**: 250, February 9, 1928. Comments on article in Eng. News-Rec., **99**: 1017, December 22, 1927.—*R. E. Thompson.*

The Big Creek Power Project. Eng. News-Rec., **100**: 82, January 12, 1928. Outline of progress on Big Creek project of Southern California Co., on which about $42,000,000 was expended in 1927.—*R. E. Thompson.*

Moffat Tunnel. Eng. News-Rec., **100**: 82, January 12, 1928. Outline of progress on 6-mile tunnel through Continental Divide. Excavation of main tunnel was completed December 10, and last 5-ton steel set of lining was placed same day. There remain 5000 cubic yards of concrete lining to be placed.—*R. E. Thompson.*

Owyhee and Other Reclamation Dams. Eng. News-Rec., **100**: 82, January 12, 1928. Outline of status of Gibson, Stony Gorge, Echo, Deadwood, and Owyhee dams. Latter will be 360 feet in height.—*R. E. Thompson.*

St. Louis Water Works Extensions. Eng. News-Rec., **100**: 83, January 12, 1928. It is hoped that entire new plant will be in operation early in 1929. Completed portions include intake and 87,000 feet of 62-inch riveted steel pipeline to Stacy Park 100-m.g. covered reservoir. Reservoir, which is 600 × 800 feet in plan, is nearly completed. Filter and pumping plants are progressing.—*R. E. Thompson.*

Chicago Sanitary District. Eng. News-Rec., **100**: 83, January 12, 1928. Since granting of permit for diversion from Lake Michigan by Secretary of War on March 3, 1925, some $36,000,000 has been expended on main sewers, pumping stations, and sewage works, of which $27,000,000 has been for sewage treatment. Cost of entire program may be as much as $155,000,000 of which

$61,000,000 has already been expended. North Side works were 89 per cent completed at close of 1927. West Side plant is about one-third completed.—*R. E. Thompson.*

Saluda Dam. Eng. News-Rec., **100:** 84, January 12, 1928. Contract for construction of earth fill dam approximately 8,000 feet long and 208 feet high was let in August by Lexington Water Power Co., a subsidiary of General Gas and Electric Corporation. Estimated cost of entire hydro-electric project is $21,000,000.—*R. E. Thompson.*

Conowingo Dam and Power House. Eng. News-Rec., **100:** 84, January 12, 1928. Brief details re status of 4800-foot dam and power house under construction on Susquehanna River by Susquehanna Power Co., a subsidiary of Philadelphia Electric Co. Expected to have first units in operation early in 1928.—*R. E. Thompson.*

Boston Metropolitan Water Project. Eng. News-Rec., **100:** 85, January 12, 1928. Data of status of $65,000,000 water supply project from Swift and Ware Rivers. Six construction shafts 310 to 650 feet deep have been sunk to tunnel grade and headings started on easterly half of 25-mile tunnel extending westerly from existing Wachusett Reservoir on Nashua River. Expenditure of $900,000 has been authorized to divert water to existing system from several small tributaries of Sudbury River to meet growing demands of district.—*R. E. Thompson.*

Steam Valves, With Special Reference to an Elimination of the Usual Pressure Losses. Fr. Hampl. Z. Zuckerind. Zechoslov. Rep., **51:** 490–8, 1927. From Chem. Abst., **22:** 2, January 10, 1928. Description of new gate, angle, and check valves in which passage through valve, when fully open, is smooth cylinder of same diameter as pipe, and without pockets to cause eddies.—*R. E. Thompson.*

Routine Preparation of Low-Conductivity Water. G. D. Bengough, J. M. Stuart and A. R. Lee. J. Chem. Soc., 1927, 2156–61. From Chem. Abst., **22:** 7, January 10, 1928. Improvements in Bourdillon's still for production of large supply of conductivity water are described. Water of conductivity as low as 0.045 reciprocal megohms at 18° has been consistently produced with this apparatus.—*R. E. Thompson.*

Preventing and Removing Boiler Incrustation. G. S. Neeley and G. Watkins. Brit. 264,551, September 8, 1925. From Chem. Abst., **22:** 32, January 10, 1928. Alternating current is applied to points of greatest thermal difference, one electrode being near water line and other at bottom of boiler shell.—*R. E. Thompson.*

Electric Ozone Generator. C. H. Shearman. Brit. 263,356, March 13, 1926. From Chem. Abst., **22:** 33, January 10, 1928—*R. E. Thompson.*

Gravimetric Determination of Calcium. A. Franke and R. Dworzak. Z. anal. Chem. 72, 129–34 (1927). From Chem. Abst., 22, 39, January 10, 1928. Determination of calcium as oxide, sulfate, or oxalate, gives good results. In determination as oxide, use of phosphorus pentoxide in desiccator is advisable as moisture is slowly absorbed when calcium oxide is dried over calcium chloride. Drying at 105° for 5 hours gives results so good that it seems strange this method has not met with more friendly reception.—*R. E. Thompson.*

Rapid Determination of Calcium and Magnesium. C. J. Schollenberger. Chemist-Analyst **16**: 2, 6–7, 1927. From Chem. Abst., **22**: 39, January 10, 1928. In filtrate from ammonium hydroxide precipitation of iron and aluminum, calcium is precipitated with oxalic acid and then, without filtering, magnesium ammonium arsenate. The precipitate is dissolved in dilute sulfuric acid and the oxalate titrated with potassium permanganate. Then the arsenic is reduced with potassium iodide to tervalent condition and oxidized iodometrically in presence of sodium bicarbonate.—*R. E. Thompson.*

American Water Installations. R. Herzfeld. Apparatebau, **39**: 235–7, 1927. From Chem. Abst., **22**: 129, January 10, 1928.—*R. E. Thompson.*

A Sensitive Reaction for Aluminum; The Colorimetric Determination of this Element. I. M. Kolthoff. Chem. Weekblad, **24**: 447–8, 1927. From Chem. Abst., **22**: 40, January 10, 1926. The indicator 1, 2, 5, 8-hydroxyanthraquinone gives, in weakly acid solution, a violet-purple lake with aluminum, flocculating on standing. To 10 cc. of neutral test solution add 0.25-1 cc. buffer solution (10 parts 5 N acetic acid, 9 parts 5 N ammonia, pH between 5.4 and 5.8 on tenfold dilution) and 0.3 cc. 0.1 per cent alcoholic indicator solution. Shake mixture and observe color after 15–20 minutes in cold or directly after heating to 50°. Color varies from intensely violet for 1 p.p.m. aluminum to faintly violet for 0.1 p.p.m., and can be detected for 0.02 p.p.m. Reaction is not influenced by alkali metals, alkaline earths, zinc, magnesium, nickel, cobalt, cadmium, lead, or chromic salts. Copper and iron are objectionable (color); tin, antimony, and bismuth give precipitates at the desired pH, removable by tartrate addition.—*R. E. Thompson.*

Ground Water in the Ordovician Rocks Near Woodstock, Virginia. G. M. Hall. U. S. Geol. Survey, Water Supply Paper **596-C**, 45–66, 1927. From Chem. Abst., **22**: 50, January 10, 1928. Six samples from wells show range of total solids of 223–508 p.p.m., and hardness from 186 to 380 p.p.m. Hardness is almost entirely carbonate, with exception of one sample. Calcium is principal base with one exception, magnesium being next. Wells in limestone are subject to pollution, not only from near-by sources but also from contamination through distant sink holes.—*R. E. Thompson.*

Technology and Uses of Silica and Sand. W. M. Weigel. Bur. of Mines Bull. **266**: 204 pp. 1927. From Chem. Abst., **22**: 142, January 10, 1928. Complete treatise on properties and uses. Bibliography included.—*R. E. Thompson.*

Quality of Water of Pecos River in Texas. W. D. Collins and H. B. Riffenburg. U. S. Geol. Survey, Water Supply Paper 596-D: 67–88, 1927. From Chem. Abst., 22: 50, January 10, 1928. Analyses of over 200 samples reported. Extreme head waters of Pecos River in New Mexico are normal calcium carbonate waters. Early in course of river it receives large quantities of calcium sulfate through solution of gypsum in soil. Sodium chloride appears in increasing quantities to Texas line when the sodium about equals the calcium and magnesium. This continues as far as Barstow. From Grandfalls down, the sodium is generally double the calcium and magnesium, and total solids are 4–5 times the quantity at Carlsbad, N. M.—*R. E. Thompson.*

The Solubility of Non-Corroding Steel in Distilled Water. H. Fitting. Naturwissenschaften, 15: 768, 1927. From Chem. Abst., 22: 52, January 10, 1928. Solubility of metals can be tested to high degree of accuracy by oligodynamic method, i.e., the action of dissolved metal on algae material. For copper the sensitivity of this test goes as far as 10^9 dilution. A 1-2-minute immersion of brass microscope objective for 1 cm. in 10–15 cc. distilled water causes latter to become destructive for algae in 24-hour test. For certain steel it was found that 4-5-hour immersion of 1 cm. steel (polished and repeatedly extracted for several weeks with water) in 15 cc. distilled water caused water to become destructive. Action was observed for steel containing nickel and also for pure iron-chromium alloy. Either iron or chromium believed to be cause.—*R. E. Thompson.*

Measuring of Milk of Lime. P. R. Tchechl. Facts about Sugar, 22: 671, 1927. From Chem. Abst., 22: 180, January 10, 1928. Device, originating in Russia, for automatically controlling density of milk of lime and for delivering it in measured quantities described.—*R. E. Thompson.*

Practical Problems of Corrosion. I. A Critical Examination of the Use of Inhibitive Chemicals. U. R. Evans. J. Soc. Chem. Ind., 46: 347–55T, 1927. From Chem. Abst., 22: 53, January 10, 1928. Six inhibitors, sodium hydroxide, sodium carbonate, sodium phosphate, potassium bichromate, calcium hydroxide, and sodium silicate, have been studied to determine pitting effect when chlorides are present in solution. Partially immersed specimens of steel were used to study water line effect. With progressive additions of inhibitor the corrosion changed from general to localized (largely at water line) to complete immunity. Inhibitors may cause serious pitting at breaks in scale. Quantity of inhibitor to give immunity is greater for rusted metal than for bare. Motion of solution reduces amount of inhibitor needed. Conclusion: Alkaline inhibitors should be added only in sufficient amounts to neutralize any acidity, but not enough to cause pitting.—*R. E. Thompson.*

Rapid Method for the Estimation of Small Quantities of Phenol in Glycerol. G. Denigès. Bull. soc. pharm. Bordeaux 65: 118–20, 1927. From Chem. Abst., 22: 136, January 10, 1928. One cc. of solution to be tested is diluted to 10 cc. with water and 1 cc. of dilution placed in test tube containing 2 cc. Millon's reagent and 0.2 cc. acetic acid. Tube is then immersed in bath of

boiling water for 5 minutes, cooled and color compared with standards prepared by treating glycerol solutions of known phenol content in same manner. —*R. E. Thompson.*

The Hydrogen-Ion Concentration of Natural Waters. I. The Relation of pH to the Pressure of Carbon Dioxide. J. T. Saunders. Brit. J. Exptl. Biol., 4: 46–72, 1926; Physiol. Abst., 11: 462. From Chem. Abst., 22: 129, January 10, 1928. Mathematical and experimental treatment of measurement of ionic concentrations of natural waters, containing valuable information on gross pitfalls into which colorimetric measurement of pH can lead investigator, with instructions, curves, and tables for accurate estimations.—*R. E. Thompson.*

The Corrosion of Iron Under Tap Water. J. Tillmans, P. Hirsch, and W. Weintraub. Gas- u. Wasserfach, 70: 845–9, 877–84, 898–904, 919–25, 1927. From Chem. Abst., 22: 53, January 10, 1928. Mechanism of rusting of iron in cold tap water discussed and literature critically reviewed. Experiments were made with chemically pure iron wire at various pH values. In presence of oxygen, pH does not directly influence velocity of rust formation as it does in absence of oxygen. High oxygen concentrations (in solution) cause iron to become passive, but in low concentrations oxygen facilitates rusting. Initial rust formation causes local cells to be set up which facilitate rusting. Still water is more active in corrosion than moving water. In natural waters containing calcium bicarbonate the relation between calcium bicarbonate and free carbon dioxide given by Tillmans and Heublein (C. A., 6: 330) appears ts be the factor determining whether corrosion will take place. Excessive carbon dioxide appears to facilitate corrosion by preventing formation of protective coating of calcium carbonate and rust. Oxygen is necessary for formation of such coating. Photomicrographs and sketches shown of such coatings. Best way of decreasing corrosiveness of water containing excess (aggressive) carbon dioxide is to pass water over marble (or to deaerate it). Potential studies and analyses of products of corrosion have been made for various pH values and other conditions.—*R. E. Thompson.*

The Evaluation of Cements. Haegermann. Tonind. Ztg., 51: 1577–80; Zement, 16: 991–8, 1927. From Chem. Abst., 22: 150, January 10, 1928. Sample of regular and one of super-portland cement were sent to 1 laboratory in Holland and 2 each in Belgium, Germany, England, France, Austria, Switzerland, and U. S. Setting times varied greatly; initial from 1:30 to 12:00 and from 1:30 to 4:40, finals from 5:10 to 20 and from 3:30 to 10 for regular and super-cements. Deviations of 10 per cent in compressive and 20 per cent in tensile strength are to be expected. H. thinks tests using fluid mix of neat cement are not suitable. For super-cements short periods of storage should be used.—*R. E. Thompson.*

The Determination of Phenols in Raw Ammonia from Coking and Gas Plants. Fr. Ulrich and K. Kather. Z. angew. Chem., 39: 229–32, 1926. From Chem. Abst., 22: 156, January 10, 1928. Phenol and each of the 3 cresols take up

3.04–3.14 molecules bromine when 50 cc. of solution containing 2.4 grams per liter are mixed with 50 cc. 0.01 N potassium bromate, 50 cc. 0.05 N potassium bromide and 10 cc. 16 per cent sulfuric acid, allowed to stand 1 hour, excess potassium iodide added and iodine titrated with thiosulfate. Mixtures gave nearly correct weight of phenols when account was taken of average molecular weight of mixture used. To remove other constituents of gas liquor, it was extracted with benzol containing 20 per cent quinoline. Five hundred cc. of liquor containing 2–4 grams phenols was washed 3 times with 100 cc. benzol solution, phenols extracted from latter with sodium hydroxide and diluted to 500 cc. Fifty cc. of this solution was diluted to 1 liter and 50 cc. taken for analysis as above, with 101 as average molecular weight of mixture of phenols. This gave better and much quicker results than older method in which gas liquor was extracted with ether, extract dried and solvent distilled off, residue dissolved in benzol, phenols washed out with sodium hydroxide, precipitated, extracted with ether, latter evaporated and residue weighed. Phenol and m-cresol are not completely extracted by this method.—*R. E. Thompson.*

The Action of Pure Water on Hydraulic Cements. RENGADE. Ciment, **32:** 370–2, 1927. From Chem. Abst., **22:** 150, January 10, 1928. Distilled water falling on halves of briquets first washed the surface grains of sand bare in 5 to 12 weeks and then dug out a crater. Specimen made of aluminous cement withstood attack for 100 weeks. A super-portland cement was next best, while lime was poorest. Calcareous Rhone River water had no effect on specimens.—*R. E. Thompson.*

A Graphical Method of Determining Heat Transfer in Pipes. W. H. MC ADAMS. Chem. Met. Eng., **34:** 599–600, 1927. From Chem. Abst., **22:** 127, January 10, 1928.—*R. E. Thompson.*

New Source of Water Supply for Newport. Engineer, **144:** 402–3, 1927. From Chem. Abst., **22:** 129, January 10, 1928. Illustrated account of new plant at Newport, Monmouthshire.—*R. E. Thompson.*

Electro-Chlorination for Textile Bleaching. C. W. MARSH. Proc. Am. Assoc. Textile Chem. Colorits, 1927, 170–2; Am. Dyestuff Rept., **16:** 650–2. From Chem. Abst., **22:** 168, January 10, 1928. Costs of making chlorine in mill under various conditions compared and necessary electrolytic equipment described.—*R. E. Thompson.*

Treating Waste Water and Conveying Slimes. PAUL HIRSCHFELDER. Chem. App., **14:** 217–9, 1927. From Chem. Abst., **22:** 181, January 10, 1928. Description of settlers used in beet sugar industry.—*R. E. Thompson.*

Corrosion Protection by Paints. P. JAEGER. Korrosion u. Metallschutz, **3:** 177–82, 1927. From Chem. Abst., **22:** 209, January 20, 1928. Discussion of protective paint coatings. Pictures of sections through paint films are given showing overlying rust as well as rust between surface and paint. Proper method of surface preparation and application of paint films discussed.—*R. E. Thompson.*

Removal of Tastes and Odors from Filtered Water by an Economical Method of Aëration. Surveyor, **72**: 352, 1927. From Chem. Abst., **22**: 288, January 20, 1928. English waters are from sources sufficiently pure that very little treatment is necessary. Taste and odor remaining after filtration can easily be removed by aëration.—*R. E. Thompson.*

South Australian Water Works and Sewerage Systems. H. E. Bellamy. J. Roy. Sanit. Inst., **47**: 583, 1927. From Chem. Abst., **22**: 288, January 20, 1928.—*R. E. Thompson.*

The Corrosion of Metals as an Electrochemical Problem. A. Thiel. Z. Elektrochem. angew. physik. Chem., **33**: 370–88, 1927. From Chem. Abst., **22**: 209, January 20, 1928. Zinc alone and in combination with other metals was immersed in acid solution to study catalytic effect of non-homogeneous metals. Evolution of hydrogen from zinc and combinations was measured, and current flowing between metals was measured and varied by resistance in external circuit. Total hydrogen was greater from couple than from zinc alone, although that from zinc was less than when zinc was alone. Difference (called "difference effect") between hydrogen evolution from zinc alone and in combination was proportional to current flowing. Current varied qualitatively with increasing over-voltage of combined metal. The zinc potential decreased when coupled. With increased solution of zinc when coupled the "difference effect" approaches as limit the product of current flowing and proportionality constant, K, between difference in gas evolution and current flowing. This proportionality constant is independent of metal coupled with zinc. Experiments were repeated for aluminum with similar results. The K has different value. Following explanation for difference effect is given: When isolated zinc dissolves hydrogen diffuses to surface of metal, keeping it saturated; should rate of diffusion decrease it would be insufficient to give saturation. In couples the rate of solution increases, increasing viscosity of boundary solution, thus decreasing the hydrogen rate of diffusion, hence the rate of hydrogen evolution. Further experiments on very pure zinc showed very slight attack except when metal was scratched. Graphite had higher hydrogen over-voltage than pure iron, so the accelerated corrosion of iron containing graphite flakes is attributed to breaking up of surface and to strains.—*R. E. Thompson.*

River Pollution. Gilbert Thomson. J. Roy. Sanit. Inst., **46**: 355, 1926. From Chem. Abst., **22**: 288, January 20, 1928. Special reference is made to present and prospective legislation. Commissioners have recommended that effluents should not contain more than 3 parts per 100,000 of suspended matter, and that oxygen absorbed should not exceed 2 parts per 100,000.—*R. E. Thompson.*

Double Chlorination of Water at Quincy. W. R. Gelston. Eng. News-Rec., **100**: 407, 1926. Double chlorination has been employed at Quincy, Ill., for 12 months and double coagulation since 1914. The primary doses of Cl_2 and alum are introduced as the water enters the mixing chamber, after

which the water receives a theoretical subsidence period of 1½ hours. The second dose of alum is applied as the water enters the second mixing chamber, and the subsidence period following this is 3 hours. Prechlorination has eliminated short filter runs. The bacteriological results were excellent until June, the number of bacteria in the settled water being usually below 100 per cc. About June 20, when the temperature had reached 73.4°F. and the turbidity was low, the bacterial count increased greatly during the purification process. The final dose of Cl_2 reduced the count to what was considered a satisfactory number. The filtered water contained very few *B. coli*, whereas in the years preceding prechlorination *B. coli* were commonly present. After September 20, when the temperature of the water was again below 60°F., the turbidity increased and the results were again excellent. The multiplication of bacteria during the summer is believed to be due to the destruction of the algae, being similar to the bacterial increase which frequently occurs following $CuSO_4$ treatment.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Hydrogen-Ion Control Reduces Cost at Small Water Filter Plant. Eng. News-Rec., **100**: 240, February 9, 1928. Brief details given of pH control at filter plant of Waterford, N. Y. Optimum point for coagulation is determined by bottle experiments and this pH is maintained by addition of sulfuric acid. Optimum is about 5.95 and variation of 0.2 either way reduces effectiveness of coagulation. Cost of chemicals with and without pH control have averaged $8.09 and $7.71 per m.g. respectively.—*R. E. Thompson.*

Oil Well Pollution Necessitates Auxiliary Water Supply. C. K. Mathews. Eng. News-Rec., **100**: 358–60, 1928. Development of oil fields in Arkansas has resulted in the pollution of the water supply of Monroe, La., derived from the Ouachita River, with oil and salt water. For 6 months of the year the NaCl content is more than 400 p.p.m., with a maximum of 2000 p.p.m. Owing to its use in a barometric condenser, the temperature of the water delivered to the city is 100–115°F. Improvements under way for correction of this situation include the creation of an impounding reservoir on the Bayou De Siard for storing an auxiliary supply for use during periods of high salt concentration, construction of a 6-million gallon per day rapid sand filter plant, remodeling of the existing coagulation basin to serve as an aërator and primary coagulation basin, and substitution of a surface condenser for the barometric condenser. The cost of the improvements, including the dam and low service pumping station, is estimated at $569,000.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Intake Tunnel at San Diego Built by Novel Pneumatic Caisson Method. Eng. News-Rec., **100**: 364–6, March 1, 1928. Illustrated description of construction of new intake tunnel at San Diego to provide ocean water for steam plant circulating system. Completed tunnel was to consist of two 4 × 8½-foot barrels, with bottom 26 feet below average ground level. Entire 1200 feet was built by pneumatic-caisson method, sinking each of 4 concrete sections separately and connecting them in place. Excavation for each of 4 caissons was carried down in open cut to ground water level and then section of con-

crete tunnel was cast without floor and with bottom edges of outside walls shaped to form cutting edges. After concrete had set, tunnel section became a caisson and was put under compressed air, excavation being carried on inside in usual manner. Tunnel traversed filled land and this method enabled obstructions to be removed as encountered. Actual cost was 20 per cent less than estimated cost of steel sheet piling method, which was next lowest in cost.—*R. E. Thompson.*

Friction Losses in a 42-inch Sewage Force Main in Baltimore. C. E. Keefer and R. T. Regester. Eng. News-Rec., 100: 360, 1928. Tests on a cast iron main which was laid in 1909 and has been in service since 1912 gave the following values: C in Hazen and Williams' formula, 102–104; *n* in Kutter's formula 0.0139–0.0144.—*R. E. Thompson (Courtesy Chem. Abst.)*

Toe Erosion Below Overflow Dams. A. E. Walden. Eng. News-Rec., 100: 369, March 1, 1928. Inspection of pool at toe of dam will almost invariably disclose that depth of pool is about ¼ height of dam, and stones up to 10–12 inches in diameter will usually be found at lower edge of pool leaving bottom at greatest depth comparatively clear except for very largest of such stones. Data given based on study described by author in Jour. New Eng. Water Works Assocn., 28: No. 3, 1914.—*R. E. Thompson.*

Po River (Italy) Flood Control Works. Eng. News-Rec., 100: 361–2, March 1, 1928. Brief outline taken from description by John R. Freeman.—*R. E. Thompson.*

Concrete Plant Placed in Spoil Bank to Obtain Gravity Flow. Eng. News-Rec., 100: 396–7, March 8, 1928. Illustrated description of concrete plant used in construction of 5-m.g. reinforced concrete covered reservoir for new water supply of Amarillo, Tex. Reservoir is 190 × 210 feet, with depth of about 20 feet.—*R. E. Thompson.*

Paver and Conveyor Form Useful Portable Concreting Plant. Eng. News-Rec., 100: 412, March 8, 1928. Brief description of ingenious arrangement of concrete road paver and portable belt conveyor used in placing concrete lining in channels of Los Angeles County Flood Control District.—*R. E. Thompson.*

Consistency of Silicate of Soda for Curing Concrete. Robert S. Beightler. Eng. News-Rec., 100: 316, 1928. The effectiveness of silicate of soda is influenced by the amount of water in the surface of the green concrete. The surface water dilutes the solution, reducing its density and viscosity. Experiments indicated that a more effective seal could be secured with same amount of chemical by properly protecting concrete until the day following laying and then applying a 36–7° Bé. soln. of the silicate.—*R. E. Thompson. (Courtesy Chem. Abst.)*

State to Control Sanitary Plans in Indiana. Eng. News-Rec., 100: 411, March 8, 1928. New rule of Indiana State Board of Health, which will go into

effect in April, requires all plans for sanitary improvements, including water works, to be submitted for approval. Supervision, which applies only to efficiency and adequacy of design, is intended principally for protection of smaller communities. Extensive stream pollution investigations are being planned.—*R. E. Thompson.*

Construction Methods on Oakland Estuary Tube. S. W. Gibbs. Eng. News-Rec., **100**: 100–5, January 19, 1928. Illustrated description of construction of largest diameter subaqueous tunnel yet undertaken which is now nearing completion under estuary between Oakland and Alameda, Cal. Total length, including approaches, is 4436 feet, and between portals 3545 feet. Two-thirds of length between portals, or 2436 feet, consists of 12 precast concrete segments built in drydock, floated to site, and then sunk to exact position in cut or trench previously dug and provided with suitable foundation.—*R. E. Thompson.*

Statistics and Prospects of Construction. Eng. News-Rec., **100**: 86–9, January 12, 1928. Statistics of construction and of costs of materials and labor in 1927.—*R. E. Thompson.*

Sewage Settling Tank Design. Warren E. Holland. Eng. News-Rec., **100**: 292, 1928. A discussion of the article by C. H. Capen, Jr. H. questions the importance of the "flowing through time" in determining efficiency of sedimentation tanks. The important factor is the ratio of time necessary to time available. This depends not merely on the time of retention but rather upon the rate of water treated in sec.-ft. per sq. ft. of water surface in the tank. —*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Sewage Settling Tank Design. C. H. Capen, Jr. Eng. News-Rec., **100**: 292, February 16, 1928. Reply to discussion of Holland (cf. previous abstract).—*R. E. Thompson.* (*Courtesy Chem. Abst.*).

New Water Works at Merritton, Ont. E. H. Darling. Cont. Rec. and Eng. Rev., **41**: 242–5, December 28, 1927. Illustrated description of new purification plant at Merritton, treating Welland Canal water, which consists of mixing chamber, coagulation basin, 4 pressure filters of $1\frac{1}{2}$ m.g.d. capacity, and chlorination equipment. Interesting feature is gasoline driven pump having 3 separate suctions connected to (1) canal, to bring raw water to sedimentation basin, duplicating raw water pumps; (2) sedimentation basin, to force settled water through basin in case gravity head is insufficient; and (3) filter water reservoir, for washing filters. In addition pump may be used to supplement main distribution pump.—*R. E. Thompson.*

A Riverman Discusses the Mississippi. Ramey Williams. Eng. News Rec., **100**: 110–1, January 19, 1928. Discussion of Mississippi River flood problem.—*R. E. Thompson.*

Paying for Flood Control. Q. C. Ayers. Eng. News-Rec., **100**: 166, January 26, 1928. Discussion of Mississippi River flood problem.—*R. E. Thompson.*

New Boston Water Tunnel, Anon. Public Works, 59: 72–3, 1928. Work is proceeding on the shafts for the new 13-mile water tunnel of the Boston Metropolitan district to connect the Wachusett reservoir to the Ware river in Coldbrook. The work is divided into two sections, the first consisting of the tunnel from the reservoir to the Ware river. This tunnel will have six shafts for construction purposes only, while shaft No. 1 at the reservoir serves as a discharge and shaft No. 8 serves as an inlet from the Ware river. The tunnel will have an area of about 127 square feet. The second section consists of 12 miles of tunnel from shaft No. 8 to the Swift river. The Swift river will be dammed to form a reservoir 18 miles long and with area of 35 square miles which will be used to store water from both the Ware and the Swift rivers.—*C. C. Ruchhoft.*

Water Treatment Plant at The Philips Glow Lamp Works, Eindhoven, Holland. Willem Rudolfs. Water Works, 67: 7–8, 1928. An unusual treatment plant, the supply for which is obtained from 42 driven wells with a capacity of 2.1 million gallons per day, is described. The water is aerated, filtered through lava to remove CO_2, treated with potassium permanganate to remove iron and manganese and filtered through sand.—*C. C. Ruchhoft.* (*Courtesy Chem. Abst.*).

Water Supply, Sewage Treatment, and Refuse Disposal in 1927. H. Burdett Cleveland. Public Works, 59: 14–18, 1928. A brief review is given of progress in the science and art of each, illustrated by notable installations during the year.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Recent Developments in Water Treatment. John R. Baylis. Water Works 67: 37–9, 1928. Developments in the chemical treatment of water have been hindered by antagonistic public opinion and the lack of efforts on the part of municipal governments to undertake research. In the past all efforts were to produce merely a safe supply but the present trend is towards the production of a certain chemical balance to prevent corrosion and most suitable for domestic use. Mechanical stirring seems to be increasing in place of the usual mixing basins. Few improvements have been made in settling basins or in the filters themselves. A great many systems of underdrains have been advocated and built without showing any decided advantages. The excess lime treatment with recarbonation is a step in advance in the treatment of hard waters.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

Water Works Trenching in Seattle. Anon. Public Works, 59: 36, 1928. Cost data for operating a ditcher for 560 hours on 15 jobs during 1927 are given. 39,147 feet of trench 2 feet wide and from 2 to 6 feet deep were dug at an average total cost of 7.2 cents per foot.—*C. C. Ruchhoft.*

Concrete Pressure Pipe at Birmingham. K. W. Grimley. Public Works, 59: 18–20, 1928. A 42-inch main 7 miles long is being laid from the filter plant to the west end of the city. Concrete pressure pipe in 12 foot lengths is being manufactured near the location. The reinforcing steel of the pipe includes

three 4 foot by 12 foot plates which are bent and welded to form a cylinder. Welded mesh reinforcement is placed inside the cylinder and a cage of steel mesh is assembled outside of the cylinder. The cylinder is placed on end in a steel form and the concrete is poured.—*C. C. Ruchhoft.*

Interesting Water Tower Designs. Anon. Water Works, 67: 45–6, 1928. The winning designs for an ornamental concrete water tower submitted in a British scholarship competition are presented.—*C. C. Ruchhoft.*

ABSTRACTS, SUB-COMMITTEE NO. 9

Joint Research Committee on Boiler Feedwater Studies

Tests of Boiler Plates of Izzett Steel (Untersuchung von Kesselblechen aus Izettmaterial der Festigkeitsgruppen), M. Ulrich. Zeit. des Bayerischen Revisions-Vereins (Munich), 32: 5 and 6, March 15 and 31, 1928, pp. 53–57 and 68–72, 13 figs. Report from testing laboratories of Stuttgart Institute of Technology on effect of cold-working temperature and duration of annealing on tensile strength, toughness and other elastic properties of special Krupp steels of Izzett class.

A New Boiler-Scale Preventive (Neues Mittel gegen Kesselstein). E. Herms. Waerme u. Kaelte-Technik (Erfurt), 30: 4, March 15, 1928, pp. 1–4. Effect and mode of use of patented solid compound "Hydrotor" or "Berghausens Kesselspeisewasser-Zusatz" (B. K. Z.) alleged to dissolve old boiler scale and to prevent formation of new.

Causes and Prevention of Corrosion. C. R. Texter. Boiler Maker, 28: 2, February, 1928, pp. 51–52. Explanation of theory; suggestions for treating feed waters; corrosion-resisting metals; among factors affecting corrosion is chemical composition of water supplies; corrosion increases proportionately with temperature; boiler-water treatment; treating for acidity; oxygen removal—deaëration; attention to kind of material used; water treatment for new boilers; corrosion of new metal. Paper read before Nat. Board of Boiler and Pressure Vessel Inspectors.

Corrosion of Iron and Steel. W. B. Lewis and G. S. Irving. Inst. Marine Engrs.—Trans. (Lond.), 40: March, 1928, pp. 63–79 and (discussion) 80–100, 14 figs. Treats theoretical side of subject, and practical outcome of such knowledge; two main types of corrosion; factors which influence corrosion; prevention.

Uses and Operation of a Deaërator as an Integral Part of the Heat Balance. System of a Power Station. L. J. C. Wigan. Elec. Engr. (Melbourne), 4: 12, March 15, 1928, pp. 443–445, 3 figs. In systems where open tanks are in use, it has become almost imperative to install deaërating apparatus; gives account of alterations made to "open" system to include deaërator, and of results obtained.

Feedwater for High-Pressure Boilers (Speisewasser fuer Hochdruckkessel) P. HERMANN. Waerme (Berlin), **51**: 4, January 28, 1928, pp. 72–75. Investigation to determine if treated boiler feedwater may be used as additional water; in general, author believes this is expedient, but gives examples to show limitations of its use.

Testing a Feedwater Softener (Erfahrungen mit einem Kesselstein Verhuetungsmittel). N. BROGLIO. Archiv fuer Waermewirtschaft, (Berlin), **9**: 4, April, 1928, pp. 111–115, 6 figs. Tests of organic water softener, "Tartricid," consisting of about 35 per cent of substance similar to tannic acid, 1 per cent mineral salt and 64 per cent water; tests show possible economy of use of organic water softeners in small boiler plants.

Water Softening with Barium Salts. C. J. RODMAN. Chem. and Met. Eng., **35**: 4, April 1928, pp. 221–223, 2 figs. Commercially, it is found that use of lime-barium water softeners is particularly adapted to waters that are impaired by excessive sulphate content; presents table showing representative operating data for lime-barium water softeners, giving location, source of water, use to which purified water is adapted, analysis of raw and treated water.

Deoxygenating Feed Water. Eng. Progress (Berlin), **11**: 4, April 1928, p. 118, 1 fig. Describes Rostex filter manufactured by Chr. Huelsmeyer, of Duesseldorf; filter is filled with special filtering packing of manganese-steel wool; this material extracts very large proportion of oxygen.

Efficient Feed Water Treatment. S. W. PARR and F. G. STRAUB, Sugar, **30**: 5, May, 1928, pp. 212–213. Embrittlement in steam boilers; four factors have been carefully considered and, in each case investigated, in trying to explain cause of these failures; brief summary of results obtained from laboratory tests.

Treatment of Feed Water for Evaporators. T. A. SOLBERG. Mar. Eng. and Shipg. Age, **33**: 5, May, 1928, p. 283. Use of sodium silicate; benefits derived; sodium silicate has no action on various metals used in any distilling plant and can therefore be used with safety.

Waste-Heat Utilization for Feedwater Treatment (Abwaermeverwertung zur Bereitung hochwertigen Speisewassers). H. BALCKE. Gesundheits-Ingenieur (Munich), **51**: 14, April 7, 1928, pp. 209–216, 20 figs. Study of formation and chemical composition of boiler scale and pipe incrustations; distillation and heating plants combined for utilization of heat of vapors; description of Balcke-Bleicken vacuum evaporator and Szamatolski high-pressure economizer.

Treated Water Increases Efficiency of Locomotives. E. M. GRIME. Water Works Eng., **81**: April 11, 1928, pp. 504 and 508, 1 fig. Railroads formerly greatly troubled by pitted locomotives and leaky flues; method to increase life of boilers: size of pumping stations increased; use of electrodes in treatment; use of zeolites and sodium aluminate.

Modernizing the Mill and Power Plant. Paper Trade Jl., 86: 14, April 5, 1928, pp. 42, 44 and 46. Water and steam purification; touches upon various factors involved, taking them up in reverse order of their influence; starts with desired results, plentiful and economical supply of dry steam, and traces various causes for moisture in and contamination of steam back to causes of scale formation; principles of boiler-water conditioning; reconstructing cycle; installation in New England; instances of progressive water and steam purification.

Corrosion in Steam Heating Systems. F. N. SPELLER. Am. Soc. Heat. and Vent. Engrs.—Jl., 34: 4, April, 1928, pp. 390–392, 4 figs. Series of tests carried out in Department of Metallurgy and Research of National Tube Co., using small experimental steam boiler, to determine acidity of condensed steam with and without boiler water treatment; description of boiler and method of operation; method for testing boiler water in steam-heating plants for alkalinity; method for determining carbon dioxide in steam condensate.

Corrosion in Steam Heating Systems. Am. Soc. Heat. and Vent. Engrs.—Jl. 34: 4, April, 1928, pp. 388–390. Discussion of paper by F. N. SPELLER published in February, 1928, Journal, p. 117. J. H. WALKER states that carbon dioxide can seldom be eliminated from steam nor is it possible to exclude oxygen entirely from ordinary heating system; F. N. SPELLER states that excess of oil must be kept out of boiler.

Condensing Water Systems Vary with Location. Power Plant Eng., 32: 8, April 15, 1928, pp. 448–452, 10 figs. Water used for cooling purposes must be suitable, not only in temperature, but in freedom from injurious acids, fish, and other debris; problems which have been met at various times in different plants and study of what has been done.

Activities of Plankton in the Natural Purification of Polluted Water. W. C. PURDY. Am. Jl. Public Health, 18: 4, April 1928, pp. 468–475, 4 figs. Three rivers thus far studied (Potomac, Ohio, and Illinois); these pollutional organisms are most numerous in that part of stream where pollution is physically evident and decrease rapidly as water regains normal condition; photosynthesis; expenditure of energy.

Chlorination of Drinking Water (Aus der Praxis der Trinkwasserchlorung). G. NACHTIGAL and P. KEIM. Technisches Gemeindeblatt (Berlin), 30: 23, March 5, 1928, pp. 329–332. Reviews chlorination practice of European and American water works; bactericidal efficiency of chlorination in conjunction with slow-sand filtration, commends prechlorination of raw water; points out effect of temperature on chlorination process.

Algae in Filtration Plants and Their Effect on the Oxygen Balance (Ueber Algen in Filteranlagen und ihren Einfluss auf die Sauerstoffbilanz). P. KEIM. Technisches Gemeindeblatt (Berlin), 30: 23 and 24, March 5 and 20, 1928, pp. 332–336 and 346–351. Review of American and European studies of water-

works algae, particularly work of WHIPPLE and HOUSTON; fluctuations in oxygen content of water filtrates; oxygen balance in filters. Bibliography.

Corrosion—The Plumber's Bug-Bear. Plumbers Trade Jl., 84: 9, May 1, 1928, pp. 954 and 956. Practical information for combating evil; discusses chemical engineer's part in work; simplest way to prevent corrosion is to remove oxygen from water; second method is to so treat water chemically that it is non-corrosive.

Hardness in Water—Its Effect and Removal. R. E. THOMPSON. Surveyor (Lond.), 6: 63, April 6, 1928, pp. 405–406. Temporary and permanent hardness; effects of hardness; softening methods; softening by base exchange lime-zeolite method. Paper presented at Can. Section of Am. Water Works Assn.

Health Policies for Control of Public Water Supplies. C. G. GILLESPIE. Am. Jl. Pub. Health, 18: 4, April, 1928, pp. 459–467. Simple control tests; operating records; sanitary surveys; water chlorination; watershed sanitation; cross-connections.

Clarification of Catskill Water-Supply by Coagulation and Sedimentation. W. W. BRUSH. Am. City, 38: 5, May, 1928, pp. 131–132. Method of introduction of alum and soda ash, and subsequent removal of alum and turbidity are of interest because of plan followed, results secured, and very large volume of water treated; results of treatment; cost per million gallons treated was, in round figures, $2.60; cost per person amounted to about six cents for nearly six months' treatment.

Electro-osmotic Preparation of Pure Water. PATIN. Indus. Chemist (Lond.), 4: 39, April, 1928, pp. 167–168, 5 figs. Apparatus described has been found to work very satisfactorily, and is first practical application of electro-osmotic principles to preparation of pure water. Abstract translated from Chimie et Industrie, February, 1928.

Iron and Manganese in Water (Ueber Eisen und Mangan im Wasser). H. THIELE. Gas- und Wasserfach (Munich), 71: 13, March 31, 1928, pp. 289–290. Report from Prussian Institute of Hygiene of Berlin-Dahlem, on deferrization and demanganization of water by use of pyrolusite, potassium permanganate, activated carbon, and other chemicals.

Automatic Water Works and Deferrization Plant (Automatisches Wasserework mit nachtraeglich eingeschalteter Enteisenungsanlage). O. KOHLER. Technisches Gemeindeblatt (Berlin), 30: 23, March 5, 1928, pp. 336–340, 3 figs. Describes electrically operated water works, pumping from wells and supplying three small communities; chemical analysis of water showing 1.9 per cent of ferric oxide; construction and operation of Halvor Breda deferrization filter; cost of deferrization.

Eliminating Tastes and Odors by Algae in Water. C. Cohn. Am. City, 38: 4, April, 1928, pp. 129–130, 3 figs. Two methods by which odors may be eliminated, one, to destroy odor and other is to destroy algae which cause odor; algicide employed, copper sulphate or chlorine; destroying water weeds; algae not harmful to health. Abstract of paper presented at Fifth Short School for Sanitarians.

Chemical Engineering Applied in New St. Louis Water Plant. C. W. Cuno. Chem. and Met. Eng., 35: 4, April, 1928, pp. 230–231, 3 figs. Details of filter house and treatment methods employed at water works in Howard Bend; from 47 billion gallons of raw water, 222,694 tons of suspended matter and 16,121 tons of dissolved solids are removed in process of purification.

NEW BOOKS

New Study on the Radius of Circle of Influence of Wells. Yashichi Yoshida. Bulletin No. 1, Kumamoto Technical College, Japan, May, 1926. A special study on the wells of Japan has resulted in a new method of determining the radius of circle of influence of wells. Bulletin gives result of author's study.—*A. W. Blohm.*

Biological Survey of the Upper Mississippi River with Special Reference to Pollution. A. H. Wiebe. Bulletin of the Bureau of Fisheries, Vol. XLIII, Part 2, 1927, Document No. 1028. This biological survey of the upper Mississippi River system was undertaken by the Bureau of Fisheries at the request of the States of Minnesota and Wisconsin. The request for the survey was brought about by the conservationists of the two states who have attributed the apparent decrease in the abundance of fish to the effects of sewage and trade wastes from Minneapolis and St. Paul. Sampling stations were established and hydrometric and dissolved oxygen data were obtained, together with studies of the relationship of bottom fauna and pollution; relationship of plankton organisms and pollution, and fish and pollution. The data presented in this paper suggest that the pollution of the upper Mississippi River is severe only (in so far as fish are concerned) during the periods of low water—that is, sometime during mid-winter (January and February) and during mid-summer (July and August).—*A. W. Blohm.*

Water Powers of Canada. Water Resources Paper No. 60, November, 1927, Department of the Interior, Canada. This is a review by provinces of the water power resources of Canada. The known available water-power in Canada is estimated to be 20,197,000 h.p. under conditions of ordinary minimum flow or 33,113,000 h.p. ordinarily available for six months of the year. The capital invested in the water-power industry in Canada is estimated to be $900,000,000 or more than that for any other single manufacturing industry.—*A. W. Blohm.*

Beton Armé. Victor Forestier. Civils de France. Flexible binding; 4 x 6 inches; 356 pp. 17 francs. Reviewed in Eng. News-Rec., 100: 289, February 16, 1928.—*R. E. Thompson.*

The Water Supply of Towns and the Construction of Waterworks. W. K. Burton. 4th Ed. **In two volumes, I. Collection and Purification Works. II. Works and Distribution.** Revised by J. E. Dumbleton. London: Crosby Lockwood and Son. Cloth; 7 x 10 inches; 137 and 160 pp. 25s. per volume in England. Reviewed in Eng. News-Rec., 100: 290, February 16, 1928.—*R. E. Thompson.*

The Design and Construction of Dams; Including Masonry, Earth, Rock-Fill, Timber, and Steel Structures, Also the Principal Types of Movable Dams. Edward Wegmann. **With a Mathematical Discussion and Description of Multiple Arch Dams.** Fred A. Noetzli. 8th. Ed., revised and enlarged. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd. Cloth; 10 x 12 inches; 740 pp. $17.50. Reviewed in Eng. News-Rec., 100: 123, January 19, 1928.—*R. E. Thompson.*

Federal Health Administration in the United States. Robert D. Leigh. New York and London: Harper Brothers, publishers. Cloth; 6 x 9 inches; 687 pp. $5. Reviewed in Eng. News-Rec., 100: 124, January 19, 1928.—*R. E. Thompson.*

Hydrology of the Great Lakes: Part III, Appendix II, Report of the Engineering Board of Review of The Sanitary District of Chicago. Robert E. Horton and C. E. Grunsky. 1927.

This is a report containing 432 pages covering the Hydrology of the Great Lakes. First are discussed the land and water area of the Great Lakes, the division of land and water areas between the United States and Canada, the mean and other stages of the Great Lakes and the relation of recent mean and minimum stages to earlier stages (1860–1884). Voluminous tables are given showing the rainfall in the basin of the Great Lakes over a range of years from 1871 to 1923, and also the winter and summer run-off of streams entering the Great Lakes. The tilting of the earth's surface is considered, as many geologists have maintained that the shore in Chicago was sinking at the rate of 1 foot per 100 years. The authors conclude that the changes in the hydrology of the Great Lakes due to land movement are at present of little importance. The effect of deforestation is discussed because of the great changes which have taken place since 1860.

The changes in lake outlets are also studied because lake levels are controlled jointly by inflow fluctuations and the outlet channel capacity at control points. The changes in the channels between the lakes are pointed out and estimates are given for the effects of the channel improvements on the levels of Lake Michigan and Lake Huron. The conclusion is that the actual lowering of the levels of these lakes through uncompensated outlet channel deepening has been at least 8 inches. The effects of the diversions are quoted from the Warren Report (p. 375) which show a lowering of Lake Michigan and Lake Huron in amount 0.43 of a foot and of Lake Erie 0.41 of a foot for the diversion at Chicago of 8800 second feet. Other diversions at the Welland Canal, Black Rock Ship Canal, New York State Barge Canal and Niagara Power Companies increase the lowering about 0.04 of a foot for Lake Michigan-Huron and 0.35 of a foot for Lake Erie.

The rainfall data for the Great Lakes have been thoroughly compiled at 47 points in the United States and 7 points in Canada for the Great Lakes basin. The mean results for the period from 1871 to 1923 are 28.2 inches per annum for Lake Superior, 33.4 inches for Lake Michigan-Huron and 34.3 inches for Lakes Erie-St. Clair. The rainfall data are separated between winter and summer. Evaporation losses are discussed with the comparison of various estimates.

The inflow to the Great Lakes from the various land areas tributary (totalling 192,600 square miles) are also discussed, in so far as the records are available. The outflow is also taken up with a summary of data available. The inflow-outflow relations are also taken up in detail.

To many the discussion of the causes of the recent period of low lake levels will appear highly important, inasmuch as in January, 1925, Lakes Michigan-Huron were 4.04 foot below their levels in January, 1885. The report states that the levels of Lakes Michigan-Huron have been lowered as a result of deepening and improving the St. Clair and Detroit Rivers. This has been a progressive matter over a period of years. It has resulted in the depression of Lake Huron as a result of channel improvement to the extent of at least 8 to 10 inches. The Chicago and other diversions have lowered the levels of Lakes Michigan-Huron from 6 to 8 inches. This accounts for a total lowering of lake levels of 14 to 18 inches. Since the Lakes Michigan-Huron have been more than 4 feet below their elevation of January, 1885, the explanation of the remaining 30 to 34 inches of lake level depression comes from the fact that the rainfall from the Lakes Superior, Michigan, and Huron drainage basins has been much less throughout the entire period, from 1885 to 1927 than immediately prior to 1885. The rainfall was abnormally high in 1880–1884, and has not been so great in any subsequent 5-year period. The difference for this period and the period of 1920–1923 was a deficiency of 6.51 inches on Lake Superior and 7 inches on Lakes Michigan-Huron. This deficiency of rainfall since 1885 has been pointed out by various observers. On the reduced runoff because of the deficiency in rainfall the report shows that the data are adequate to account for a total lowering of the levels of Lakes Michigan-Huron of roundly 36 inches since 1885, because of the reduced water production of the upper lakes. With cycles of time rainfall years lake levels will rise, but even were there no diversion with cycles of deficient rainfall years there would be cycles of depression. The authors conclude that the only complete and adequate remedy for control of lake levels is regulation.

The report contains a number of tables and diagrams of interest to hydraulic engineers. It is of particular interest to those who are interested in the facts concerning the fluctuations of the levels of the Great Lakes, inasmuch as it offers a direct and authentic discussion of the various elements involved and affords convincing proof that the major portion of the lowerings are caused by deficiency in rainfall and changes in the channels between the lakes, and not by the Sanitary District of Chicago.

The tables quoted show that, of a total lowering of 48 inches or more in Lakes Michigan-Huron, the Sanitary District may be charged with less than 5 inches.—*Langdon Pearse.*